Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 227 JANUARY, 1939 No. 1

PRESENT STATUS OF THE THEORY OF THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON COSMIC RAYS.*

BY

M. S. VALLARTA, Sc.D., Ph.D.,

Massachusetts Institute of Technology, Cambridge, Massachusetts.

ABSTRACT.

The present communication is intended to cover a brief summary of the results obtained through analysis of the motion of charged particles in the earth's magnetic field and includes the following topics:

(*a*) The main cone, in any direction within which particles of a given energy may arrive at a given point on the earth. Latitude and azimuthal effects. Special cases of the latter: north-south and east-west asymmetries. The ratio of positive and negative primaries.

(*b*) The shadow cone, outside of which no particles of a given energy may arrive at a given point on the earth.

(*c*) The penumbra, i.e. the region intermediate between the main cone and the shadow cone in which certain directions are allowed and the others forbidden.

(*d*) The eccentricity of the earth's magnetic center and the longitude effect. The position of the earth's magnetic center. The earth's magnetic quadripole.

(*e*) The earth's magnetic field and the galactic rotation effect.

(*f*) The sun's magnetic field and some of the consequences of its existence. The knee of the latitude effect. Solar diurnal and annual variations.

(*g*) Preliminary communication on magnetic storms and cosmic ray intensity.

We propose to report on certain of the more important results obtained in the last few years through analysis of the motion of charged particles in the earth's magnetic field, and

* Based upon a paper read at the Chicago Cosmic Ray Symposium, June 29–30, 1938.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

a number of problems related thereto. Our considerations apply therefore to charged primary particles.

Many names should be recalled in connection with this work. First we should name Carl Störmer who first studied this question in connection with the problem of the aurora polaris, set up the equations of motion and derived a number of important consequences that we shall have occasion to mention repeatedly in the sequel. Part of our own work has been carried out in close collaboration with Professor Georges Lemaitre, of the University of Louvain, and his former students, among whom we should mention Messrs. Bouckaert, de Borman, Godart, Tchang and others. Among our own students who have collaborated with us and made important contributions to the subject we would like to recall Drs. Schremp, Albagli and Baños, and Messrs. Kusaka and Graef.

From the analysis of the earth's magnetic field it has been known since the days of Gauss that the dipole and quadripole terms (first and second order terms) are sufficient for its representation on the earth's surface. Of these terms the most important one at distances from the earth's surface comparable with the earth's radius is the dipole component which therefore should govern in the main the motion of charged particles; the quadripole component can then be looked upon as a perturbation. It is also known that the magnetic dipole and quadripole are not located at the earth's center, but rather at a point called the earth's "magnetic center" first located by A. Schmidt at approximately 340 km. from the earth's center in latitude 7° N. and longitude 160° E.

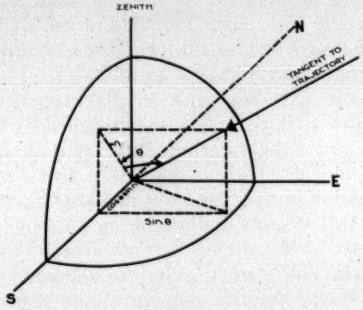
The chief theoretical result of our analysis is the discovery of the existence of a cone of many sheets centered at the observer (called the "allowed cone") within which particles of a given energy must arrive at a given point of the earth. The question of the structure of this cone and the determination of its boundaries is one of our main subjects of interest and is fundamental for the understanding of many experimental results relating to cosmic rays. Another fundamental theoretical result [1] is that if the distribution of cosmic

[1] Liouville's theorem was first applied to the present problem by G. Lemaitre and M. S. Vallarta, *Phys. Rev.*, **43**, 88, 1933, and independently by E. Fermi and B. Rossi, *Rend. della R. Accad. Naz. dei Lincei*, **17**, 346, 1933. It has been dis-

rays at infinity is isotropic then the intensity along any allowed direction is exactly the same (Liouville's theorem).

To begin with we elucidate the representation of the allowed cone, which we have adopted in our work. We imagine the unit sphere (Fig. 1) centered at the observer at a point on the earth. This sphere is divided into two hemispheres by the horizontal plane at the point of observation. Since cosmic rays come only from above, that hemisphere above the horizontal plane alone has any significance. We picture then a critical orbit, to be more fully discussed below, separating

FIG. 1.



Cone representation.

allowed and forbidden directions and the tangent to this critical orbit at its point of arrival. This tangent intersects the unit sphere at a point which we project orthogonally on the horizontal plane, and which is a point of the boundary of the allowed cone. If the sequence of all such points determined by critical trajectories, in the sense specified above, is projected on the horizontal plane the result is the boundary of the allowed cone. Any critical direction is defined by two angles: η and θ. The former is the angle between the projection of the tangent on the meridian plane and the zenith

cussed at length by W. F. G. Swann, *Phys. Rev.*, **44**, 224, 1933. This application of Liouville's theorem has been criticized by C. Störmer, Publ. Univ. Obs. Oslo, No. 10, 1934, and *Phys. Rev.*, **45**, 835, 1934. His objections are without foundation.

direction, and conventionally is counted positively towards the north; the latter the angle between the tangent and its projection on the meridian plane and is counted positively eastwards.

The main problem is the determination of critical trajectories. The analysis shows that they may be of two kinds:[2] trajectories asymptotic to the family of outermost periodic orbits, and trajectories tangent to the earth before arriving at the point of observation. The former delimit that region within which all directions are allowed by following trajectories which directly go to infinity without forming loops. This region we have called the "main cone."[3] The latter, or more precisely that particular kind of the latter which are tangent to the earth but do not form loops, delimit that region outside of which no directions are allowed. This region we have called the "shadow cone."[4] Between the main cone and the shadow cone there is a region, called by us the "penumbra,"[5] within which certain directions are allowed and the rest forbidden. The boundaries of this region may be trajectories either of the first or second kinds, and all allowed directions in this region go to infinity by forming loops. Such trajectories we have called reëntrant orbits. The situation is illustrated in Fig. 2 where A is the boundary of the main cone, B that of the shadow cone and C one of many bands of "light," i.e. of allowed directions, in the penumbra. The line labelled $\gamma_1 = 1$ is the Störmer cone. This is a right circular cone with vertex at the observer, and has the property that outside of it the region containing the earth and the region containing all trajectories issuing at infinity are disconnected. It establishes an absolute upper limit to the allowed cone which, as will be more fully discussed later, is not always reached. Its existence was first discovered by Störmer,[6] and it was the only one which was used in early

[2] G. Lemaitre, *Ann. de la Soc. Sci. de Bruxelles*, A54, 162, 1934.

[3] G. Lemaitre and M. S. Vallarta, *Phys. Rev.*, 50, 493, 1936.

[4] E. J. Schremp, *Phys. Rev.*, 54, 158, 1938.

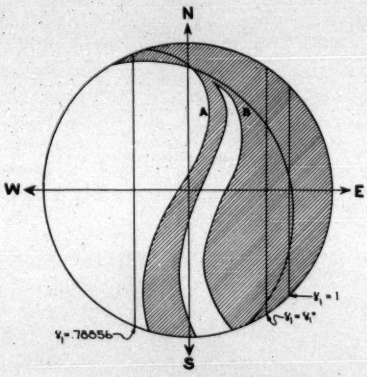
[5] R. Albagli Hutner, *Phys. Rev.*, Jan. 1, 1939.

[6] C. Störmer, Publ. Univ. Obs. Oslo, No. 10, 1934, where references to his previous work will be found.

discussions of the latitude and the east-west asymmetry by Rossi and Fermi,[7] and by Störmer.

To illustrate the role of asymptotic orbits we shall now take up in detail the simplest case: that of equatorial orbits. The equations of motion for this case are integrable in terms of elliptic functions and the manifold of all trajectories is easily analyzed. In the equatorial plane there is a very well known periodic orbit: the circular orbit. If we consider any point on the earth (Fig. 3) at the magnetic equator (plane

FIG. 2.

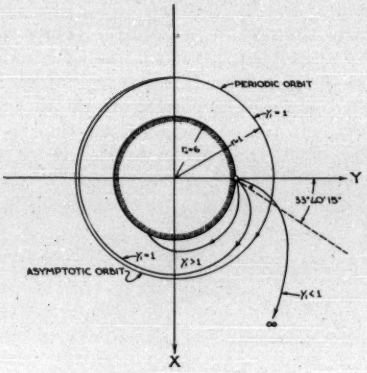


Diagrammatic cone.

perpendicular to the dipole axis) there are in general two sorts of orbits arriving at this point: orbits issuing from other points of the earth such as that labelled $\gamma_1 > 1$ which cannot be the trajectories of a cosmic ray particle coming from infinity, and orbits coming from infinity such as that labelled $\gamma_1 < 1$ which can be trajectories of primary cosmic rays. If now we inquire what kind of orbit separates orbits of the first sort from orbits of the second sort we find that it is an orbit which has the property of coming always closer to the periodic orbit while winding around the earth an infinite

[7] B. Rossi, *Phys. Rev.*, **36**, 606, 1930, *Ricerca Scientifica*, **1**, 561, 1934, E. Fermi and B. Rossi, *Rend. della R. Accad. Naz. dei Lincei*, **17**, 346, 1933.

FIG. 3.



Asymptotic equatorial orbit.

FIG. 4.

Bush's differential analyzer.

number of times, and therefore reaches the periodic circular orbit only after infinite time. This is the asymptotic orbit labelled $\gamma_1 = 1$ in Fig. 3. Such asymptotic orbits therefore separate allowed directions from forbidden directions in the equatorial plane. An interesting fact is that orbits of the sort discussed here cannot form loops, but must go either directly to infinity or to the earth.

We now come to the question of the specification of the energy of a particle and the meaning of the parameter γ_1, already introduced in the preceding discussion. The radius of the circular orbit depends on the energy of the particle describing it and increases as the energy decreases. If now we take the ratio between the radius of the earth and the radius of the circular orbit, that pure number becomes a measure of the energy of the particle. When the energy of a particle is measured in this way we shall refer to it as its energy in Störmers. A table of equivalence between the energy measured in Störmers and the energy measured in electron-volts, for electrons and protons, is given herewith (Table I).

TABLE I.

Energy in Störmers.	Energy in $10^9 e-V$ (bev) electrons.	Energy in $10^9 e-V$ (bev) protons.
0.1	0.596	0.172
0.2	2.38	1.62
0.3	5.36	4.49
0.4	9.54	8.61
0.5	14.9	14.0
0.6	21.5	20.5
0.7	29.2	28.2
0.8	38.2	37.2
0.9	48.3	47.3
1.0	59.6	58.5

The parameter γ_1 has a very direct physical meaning and a great deal of importance in the theory we are discussing here. It is the component along the dipole axis of the moment of momentum of the particle at infinity, and is a constant of the motion.

Out of the equatorial plane the equations of motion are no longer integrable, and recourse must be had to methods of numerical or mechanical integration. The former are very

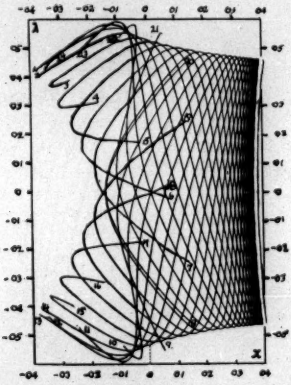
laborious and require an almost prohibitive amount of time and work when, as in the present case, several hundred trajectories of different kinds are required. Fortunately there is available at the present time a method of mechanical integration, developed at the Massachusetts Institute of Technology by Dr. Vannevar Bush which is admirably suited for the needs of the present problem. We shall not enter into the details of this method which has been already described in the literature by Bush himself,[8] as well as its application to the present problem by Lemaitre and Vallarta.[9] Here we shall merely say that the saving of time and effort is so considerable that the required number of critical trajectories, asymptotic and otherwise, can be and has been obtained within a reasonable time and with a moderate effort. We shall now proceed to a brief description of some of the results obtained with the help of Bush's differential analyzer.

The circular periodic orbit in the equatorial plane, to which reference has already been made, is the first and the simplest member of a family of periodic orbits which oscillate on either side of the equator and which were first discovered by Störmer [10] and treated afterwards more fully by Lemaitre.[11] These orbits are unstable in the sense that they admit a positive characteristic exponent. They exist only in the range between $\gamma_1 = 1$ and $\gamma_1 = 0.788541$, as first pointed out by Lemaitre and Vallarta [12] and then further elaborated by Lemaitre [13] and by Godart.[14] Each one of these periodic orbits has an asymptotic family which, as shown by Lemaitre and Vallarta, has the property of separating orbits which come directly from infinity (without forming loops) from orbits which either return to the earth or else go to infinity after having formed loops. Asymptotic orbits form the boundary of what we have called the main cone. An example of such an asymptotic family is shown in Fig. 5 which refers to γ_1

[8] V. Bush, JOURNAL OF THE FRANKLIN INST., 212, 447, 1931.
[9] G. Lemaitre and M. S. Vallarta, loc. cit., ref. 3.
[10] C. Störmer, *Zeits. für Astrophys.*, 1, 237, 1931.
[11] G. Lemaitre, *Ann. de la Soc. Sci. de Bruxelles*, A54, 194, 1934.
[12] G. Lemaitre and M. S. Vallarta, *Phys. Rev.*, 43, 87, 1933.
[13] G. Lemaitre, loc. cit., ref. 11.
[14] O. Godart, *Ann. de la Soc. Sci. de Bruxelles*, A58, 27, 1938.

$= 0.85$.[15] After a sufficient number of such asymptotic families has been determined the boundary of the main cone may be determined in the following way. For any given latitude and energy the angle η is read off directly from the asymptotic trajectory going through that point and the angle θ is calculated from a well-known formula due to Störmer. For a further elucidation of Fig. 5 the following remarks seem necessary. The figure represents a conformal transformation of the meridian plane in which latitude and distance from the

FIG. 5.



Calculated family of asymptotic orbits for $\gamma_1 = 0.85$.

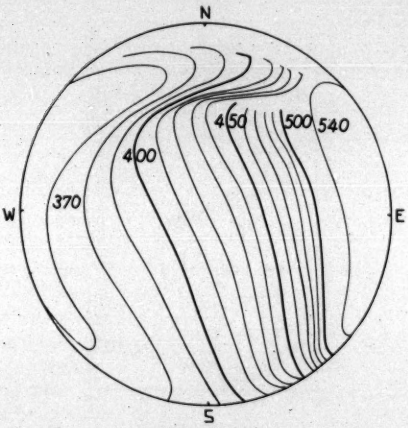
dipole are plotted as Cartesian coördinates. For any value of the energy the earth is represented by a straight vertical line. Any given energy and latitude thus corresponds to a point in the meridian plane. Once a trajectory in the meridian plane has been determined, the space trajectory is obtained from it by another integration which gives the motion of rotation of the meridian plane about the magnetic dipole axis: the actual motion, as early shown by Störmer, is the resultant of two component motions, one in the meridian plane, the other of the meridian plane. A knowledge of the

[15] A. Baños, Jr., Ph.D. Thesis, M.I.T., Jan., 1938.

latter is not necessary for our problem, for if an orbit in the meridian plane goes to infinity, so does the space trajectory, and likewise for an orbit returning to the earth.

The main cone for latitude 30° is reproduced [16] in Fig. 6. The figure has been drawn for positive particles and for the northern hemisphere, so that the allowed regions lie to the west of the boundaries shown. For negative particles the boundaries would be the mirror images of those shown, with

FIG. 6.



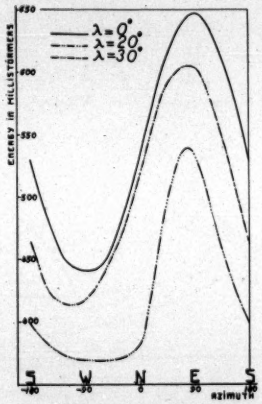
Main cone $\lambda = 30°$.

respect to the north-south plane; for the southern hemisphere it is the mirror image of either the positive or the negative cone with respect to the east-west plane. The numbers beside several boundaries give the corresponding energy in millistörmers. The most remarkable feature of the main cone, exhibited in Fig. 6, is the strong asymmetry of the boundaries with respect to the east-west plane. A consideration of Fig. 6 shows immediately that the range of energy which can reach a point of the earth (in the present example, a point at latitude

[16] G. Lemaitre and M. S. Vallarta, *Phys. Rev.* **49**, 719, 1936, and loc. cit., ref. 3.

30°) is not the same at all azimuths. Consequently there must be a variation of intensity at a given point of the earth and fixed zenith angle, but for different azimuths (azimuthal effect), of which special and very important cases are the north-south and east-west asymmetries. Suppose now that a circle is traced on Fig. 6 corresponding to a fixed zenith angle. This circle intersects the boundaries of the cones of different energies at azimuths which can be read off directly on the figure. Thus the curve for the azimuthal effect (Fig. 7) is

FIG. 7.



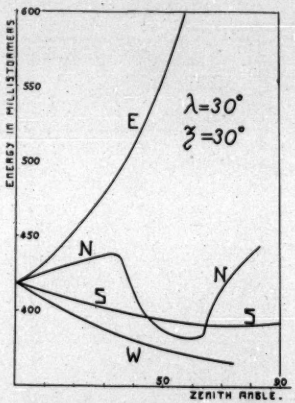
Azimuthal effect. Zenith angle 45°.

obtained, which gives the minimum energy required to reach the latitudes shown at a fixed zenith angle of 45° and azimuths shown by the abscissas. Unfortunately no systematic comparison with the experimental azimuthal effect is possible at the present time because no systematic measurements covering a complete turn of the horizon have been made.

Interesting special cases of the azimuthal effect are the north-south and east-west asymmetries. A comparison of the energy ranges involved in each of them is given in Fig. 8, where the east-west asymmetry has been drawn for positive

particles. It is readily seen that the former does not depend on the sign of the primaries, whereas the latter depends on the difference between positives and negatives. Historically the latter was the first to be investigated, both experimentally and theoretically on the basis of the theory of the Störmer cone, by Rossi,[17] and the fact that the experiment gave a greater intensity from the west was usually interpreted to mean that primary cosmic radiation is predominantly posi-

FIG. 8.



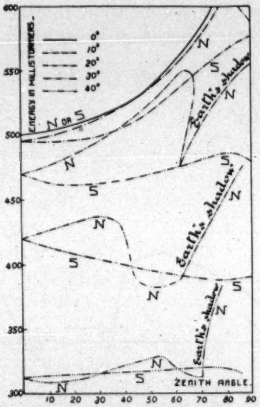
North-South and East-West asymmetries.

tively charged. It should be borne in mind that this conclusion refers strictly to that energy range which is explored by the east-west asymmetry at the latitude where the experiment is made, and that it is by no means certain that the totality of primary rays is predominantly positively charged. Since the north-south asymmetry depends upon the sum of positives and negatives, whereas the east-west asymmetry depends on their difference, a comparison between them gives valuable information as to the ratio of positives and negatives in a given energy range. This point is further examined in

[17] B. Rossi, loc. cit., ref. 7.

Dr. T. H. Johnson's paper in the present symposium and will not be further dealt with here. The theoretical north-south asymmetry is shown in Fig. 9 and a comparison with experiments of Dr. T. H. Johnson [18] is shown in Fig. 10. The theoretical curve is largely insensitive to the particular form of the energy distribution which is assumed for the primaries, since it involves only a very small energy range.

FIG. 9.



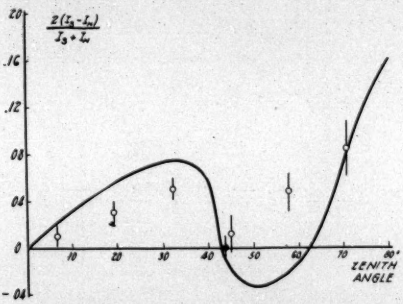
North-South asymmetry.

For particles of any given energy the main cone gradually opens up as the latitude increases, so that from a certain latitude on the cone is completely open and particles of that energy may come from all directions. For particles of energy below 414 millistörmers the main cone does not begin to open until a certain critical latitude is reached, for energies higher than this limit the main cone is already open at the equator. This is the way the present theory accounts for the latitude effect.

[18] T. H. Johnson, *Phys. Rev.*, **47**, 91, 1935. For the theory of the north-south effect see G. Lemaitre, M. S. Vallarta and L. Bouckaert, *Phys. Rev.*, **47**, 434, 1935, and G. Lemaitre and M. S. Vallarta, *Phys. Rev.*, **49**, 719, 1936.

The theory, as shown, is competent to give a complete answer to questions relating to the minimum energy that a particle must have to arrive at a given point of the earth and from a given direction. The curve labelled "zenith" (Fig. 11) gives the minimum energy that a particle must have to arrive at the latitude given by the abscissa and in the vertical direction. The top curve gives the least energy that a particle must have to arrive in any direction at the latitude given by the abscissa. The lowest curve gives the least energy that a particle must have to arrive at all at the latitude given by the abscissa, in the western direction along the horizon if positive,

FIG. 10.

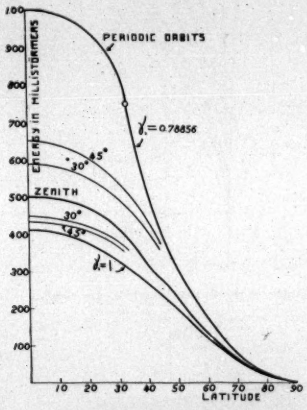


North-South asymmetry. $\lambda = 29°$ N. Alt. = 4300 M.

in the eastern direction if negative. The lower curve labelled 45° gives the least energy that a particle must have to arrive at 45° to the zenith and in a certain azimuth, the upper curve similarly labelled gives the least energy that a particle must have to fill up all directions within 45° from the zenith. Similarly for the curves labelled 30°. It should be emphasized in this connection that the familiar formula for calculating the energy required to arrive in the vertical direction at a latitude λ: $V = K \cos^4 \lambda$ assumes that the Störmer cone is always actually reached, i.e. that $\gamma_1 = 1$ is always a possible value. Such is not the case, and the use of this formula indiscriminately may lead to gross errors.

We now take up in order the question of the shadow cone and penumbra. Referring back to Fig. 2 it is seen that beginning at a certain azimuth and zenith angle the main cone is continued by the shadow cone. This point is characterized by the fact that the asymptotic trajectory at that point becomes at the same time tangent to the earth, beyond it the main cone is continued by trajectories which do not form loops but are tangent to the earth. Such trajectories are exhibited in Fig. 12 which shows a family of trajectories

FIG. 11.

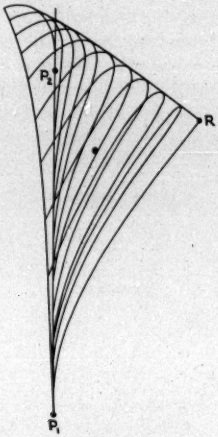


Minimum energy of arrival.

tangent to the earth for a constant value of the energy.[4] For any value of the energy such trajectories can exist only within a definite range of latitude, i.e. within the two limits marked off by the points P_1 and P_2 of Fig. 12. The lower limit is a self-reversing trajectory, all trajectories starting along the line of constant energy with a vertical tangent cannot return to the earth; the upper limit is characterized by a point of inflection along which the x-acceleration (component of acceleration parallel to the abscissa) vanishes. The first thing to do, therefore, is to determine the two loci of zero x-acceleration and of vertical tangent for all self-reversing orbits, for every

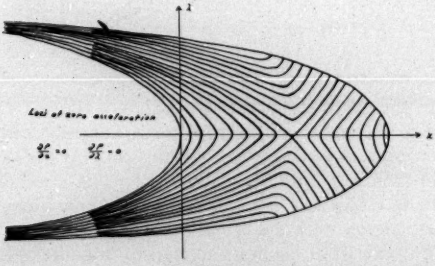
value of γ_1. The latter locus we shall call for brevity "the locus of zero x-velocity." The locus of zero acceleration is

FIG. 12.



Family of simple shadow orbits (x = const.).

FIG. 13.



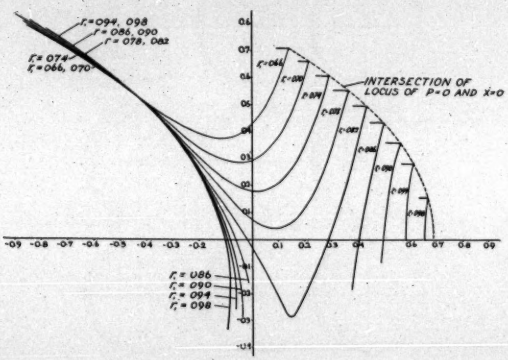
Loci of zero acceleration.

known analytically from the equations of motion and is shown for different values of γ_1 in Fig. 13. The equator and the

curve to the extreme left are the loci of zero component of acceleration parallel to the axis of ordinates: the whole plane is divided by then into four "quadrants," in which the sign of the acceleration alternates from positive to negative. The other lines are the loci of zero x-acceleration for different values of γ_1: the sign of this component of acceleration alternates from positive to negative as these loci are crossed.

The loci of zero x-velocity are not given analytically but may be easily found by means of Bush's differential analyzer. To do this one needs only to obtain a family of trajectories

FIG. 14.



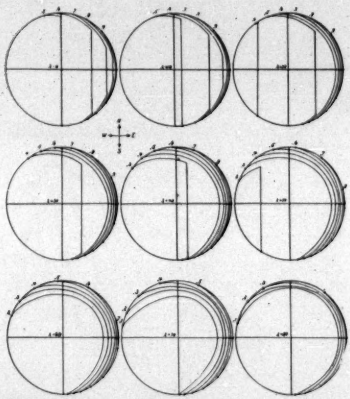
Loci of zero x = velocity.

intersecting orthogonally the boundary of Störmer's forbidden region in the meridian plane,[19] for each value of γ_1, and continue these trajectories until they have a vertical tangent. The loci obtained in this way are exhibited in Fig. 14, which shows several features of great interest. The outer points where a locus intersects the equator are the points where the outer principal family of periodic orbits, to which the orbits which form the boundary of the main cone are asymptotic, intersect the equator. It is seen that in general there are two

[19] The forbidden regions in the meridian plane have been repeatedly published by C. Störmer. See for instance loc. cit., ref. 10.

principal periodic orbits: the outer and the inner. For a certain value of γ_1 the locus in question becomes tangent to the equator and the two principal periodic orbits collapse into one, beyond it (for smaller values of γ_1) there can be no periodic orbits. This is the significance of the limiting value $\gamma_1 = 0.788541$ for which periodic orbits disappear, a value of great theoretical importance, the existence of which Lemaitre and Vallarta [12] had already pointed out.

FIG. 15.



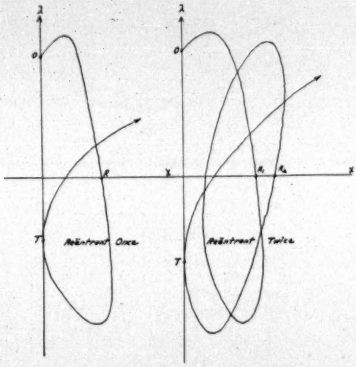
Shadow cone.

Once the region where shadow trajectories (i.e. forming the boundary of the shadow cone) may exist has been mapped out, the remaining program of investigation for the determination of the shadow cone, for all latitudes and energies, is clearly defined, and consists in determining by means of the differential analyzer families of shadow trajectories such as shown in Fig. 12. The result is shown in Fig. 15, which gives the shadow cones for all latitudes and energies. At the equator the main cone is the complete allowed cone.

Neither the trajectories forming the boundary of the main cone, nor those forming the boundary of the shadow cone are

reëntrant orbits. Trajectories forming loops constitute the totality of allowed motions in the region of penumbra,[20] and the boundaries of the allowed bands are also reëntrant orbits. Fig. 16 shows two examples of shadow trajectories of higher kind, having one and two loops. The first kind of trajectory gives rise to the most important bands in the penumbra. To illustrate the difficulty of the analysis in this region, Fig. 17 gives an example of a family of orbits all for the same energy and latitude, and Fig. 18 gives an idea of the types of reëntrant

FIG. 16.

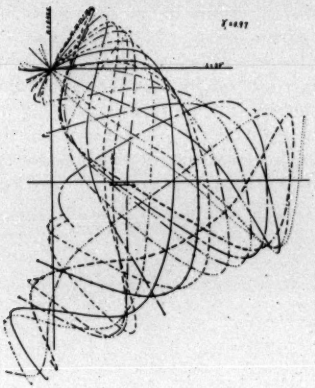


Shadow trajectories of higher order.

orbits which occur. It would be idle to attempt to give here even a brief idea of the sort of intricate analysis which is involved in the study of the penumbra, and we must be satisfied with a summary of the results. The complete allowed cone for the latitude and energy indicated in the figure, is shown in Fig. 19. It will be noticed that the Störmer cone is not reached. How closely the Störmer cone can be reached for particles of different energies is shown in Fig. 20. It will be seen that if the latter is reached at all, it is only by particles of energy below the critical value 414 millistörmers, and how

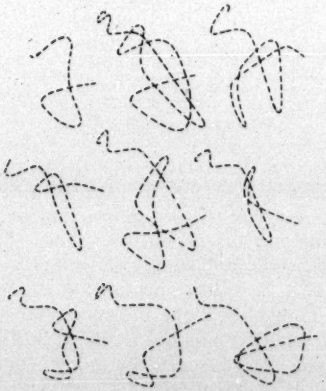
[20] R. Albagli Hutner, loc. cit., ref. 5.

FIG. 17.



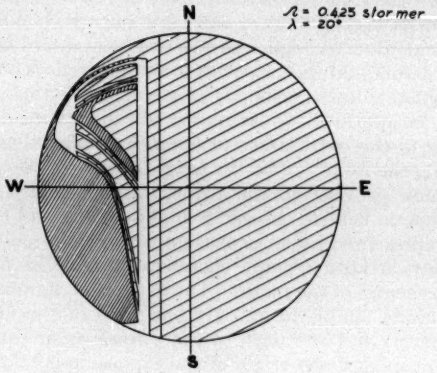
An example of a family of trajectories for fixed energy and latitude.

FIG. 18.



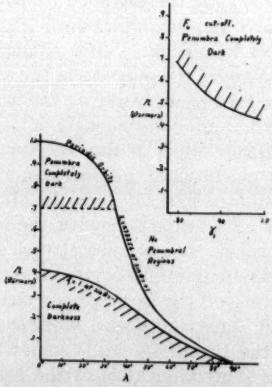
Types of reëntrant orbits.

FIG. 19.



Allowed cone. Forbidden regions cross-hatched N.E. to SW.

FIG. 20.



The F_0 cut-off.

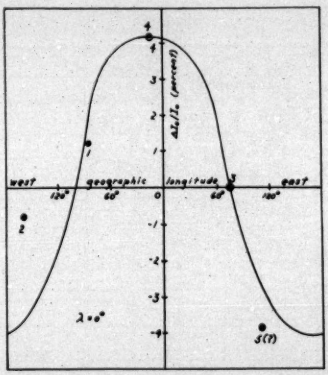
this happens is a problem which still requires elucidation. At low latitudes the region outside the main cone is practically dark (there are only few and very narrow bands in the penumbra) while at high latitudes the penumbral bands are very numerous and wide so that the shadow cone is practically the complete allowed cone. The penumbra is thus only important at intermediate latitudes, but in any case its contribution to the total intensity is much smaller than that of the main cone.

We now go over to the theory of the longitude effect. The magnetic field of the earth at its surface and elsewhere can be represented by an expansion of Legendre polynomials about any arbitrary point chosen as origin, in particular about the center of the earth. The expansion, however, takes a particularly simple form, only one term of the first order (dipole term) and one term of the second order (quadripole term) remaining if the origin of the expansion is taken not at the earth's center, but at the earth's magnetic center, a point about 340 km. from the earth's center, in latitude 6° N. and longitude 165° E. If the magnetic dipole is placed not at the center of the earth, but at the magnetic center, the immediate consequence is that the distance from the geomagnetic equator, or from any geomagnetic parallel, to the dipole is a periodic function of longitude. Since changing the distance to the dipole also changes the opening of the allowed cone, one must expect differences of intensity at the same latitude and different longitudes, and consequently a longitude effect.[21] The expected longitude effect at the equator is shown in Fig. 21, and the lines of constant intensity of cosmic radiation at the earth (combined latitude and longitude effects) are shown in Fig. 22. A comparison with the available experimental data, however, shows discrepancies which appear mainly in that the maximum of the equatorial longitude effect, instead of being off the west African coast, is somewhere off the west South American coast, while the minimum, instead of being in the Pacific Ocean is somewhere west of the Malay Peninsula. The magnitude of the longitude effect is,

[21] For the theory of the longitude effect see M. S. Vallarta, *Phys. Rev.*, **47**, 647, 1935. See also *Nature*, **139**, 24, 1938.

nevertheless, as predicted by theory. This indicates a serious discrepancy between the position of the earth's magnetic center as determined from magnetic measurements on the earth and as determined from cosmic ray measurements. This discrepancy is somewhat removed, as pointed out by Lemaitre, but not quite completely, if account is taken of the facts, first, that the "magnetic vertical," i.e. the line connecting the point of the earth in question with the earth's magnetic center should be used instead of the ordinary vertical, and

FIG. 21.



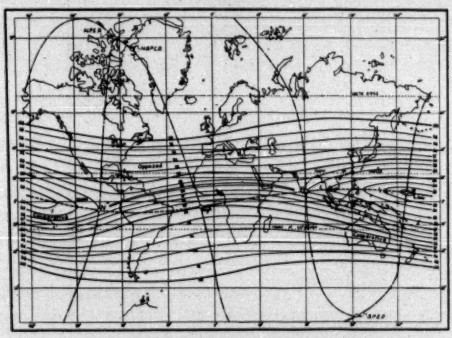
The longitude effect along the geomagnetic equator.

second, that account should be taken of the fact that there is a possibility that the primaries may consist of a mixture of positives and negatives. There is also the possibility that this discrepancy is not real, but has been introduced into the measurements by the fact that in many cases the experimentally measured intensities represent the results of single measurements which may have been affected by disturbances of short duration, mainly magnetic storms.

An important conjecture which has been repeatedly voiced in the literature and which can be easily tested by means of the longitude effect is the influence of the quadripole on the

observed cosmic ray intensity. If the quadripole is important and if an harmonic analysis of the experimental equatorial intensities is made, one should expect in addition to a fundamental of full period (360°) a second harmonic of half period (180°), the first arising from the eccentricity of the dipole (and quadripole) and the second from the plane of symmetry of the quadripole. Such an analysis has been made by the author by taking all the experimental intensities measured at the geomagnetic equator to date, and subjecting the resultant curve to harmonic analysis. The result is that outside of a well marked full period fundamental of about 4 per cent.

FIG. 22.



Combined longitude and latitude effect.

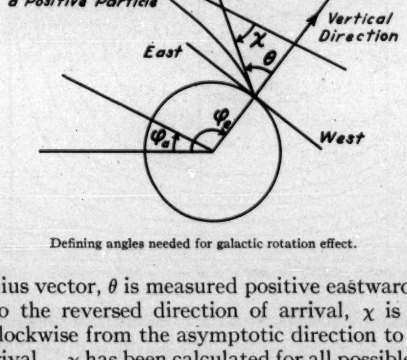
amplitude, there are a number of small higher harmonics of amplitudes 0.1–0.3 per cent. but no indication of a prominent half-period harmonic. This result must be interpreted to mean that as far as the present precision of experimental cosmic ray intensities goes, there is no indication of an important influence of the quadripole term.

The effect of the galactic rotation on the intensity of cosmic radiation was first investigated by Compton and Getting,[22] who made the calculation neglecting the deflection of cosmic ray particles by the earth's magnetic field and then

[22] A. H. Compton and I. A. Getting, *Phys. Rev.*, 47, 817, 1935.

made a rough estimate of this effect. Swann [23] then showed how the effect of the deflection can be taken into account if the direction of motion of the particle at infinity is known. The angle of deflection of a particle reaching the earth from infinity and consequently the direction of motion at infinity, can be easily calculated in the case where the motion is restricted to the equatorial plane. From Fig. 23 it is seen that the angle of deflection χ is given by $\chi = \varphi_e - \varphi_a - \theta$ where φ_e and φ_a are the polar angles of the trajectory at the earth and at infinity, respectively. The following conventions are adopted: φ is measured positive westward from the polar axis

FIG. 23.



Defining angles needed for galactic rotation effect.

to the radius vector, θ is measured positive eastward from the vertical to the reversed direction of arrival, χ is measured positive clockwise from the asymptotic direction to the direction of arrival. χ has been calculated for all possible values of θ and for several values of the energy. The result is shown in Fig. 24 where χ is in radians and θ in degrees. For $r_e = 0.5$ and $\theta = 0$, $\chi \to \infty$ since this is an asymptotic orbit.

We shall define the intensity of cosmic radiation I, as usual, as the number of particles received per second per unit area. Then if $f(E)$ is the energy distribution function at infinity, the intensity of cosmic rays arriving in the vertical

[23] W. F. G. Swann, *Phys. Rev.*, 51, 718, 1937.

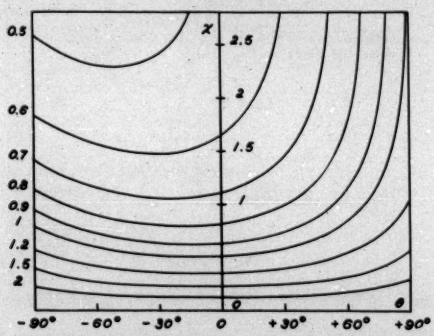
direction at the earth at rest with respect to the distribution at infinity (i.e. with respect to the extra-galactic observer) is, by Liouville's theorem,

$$I = \int_{E_0}^{\infty} f(E)dE,$$

where E_0 is the least energy the particle can have to arrive at the equator in the vertical direction. When the motion of the earth is taken into account the intensity is given by,

$$I^1 = \int_{E_0}^{\infty} \frac{f(E)dE}{(1 - \beta \cos \omega^1)^3},$$

FIG. 24.

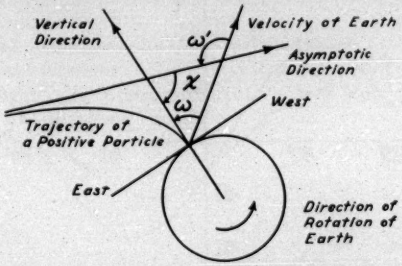


Deflection angle χ as a function of arrival angle θ.

where β is the ratio of the velocity of the earth to the velocity of light, and ω^1 is the angle between the velocity of the earth and the reversed path of the trajectory at infinity. From Fig. 25 it is seen that $\omega^1 = \chi + \omega$ where ω is the angle between the velocity of the earth and the vertical at the point of observation. The lower limit of the integral above, according to W. F. G. Swann should be $E_0/(1 + \beta \cos \omega_0^1)$ obtained by applying a Lorentz transformation to the energy E_0 of the particle at infinity. We cannot agree with this. With respect to the terrestrial observer the limiting energy in the earth's

magnetic field is E_0 and the distribution with respect to him is anisotropic as indicated by the factor $(1 - \beta \cos \omega^1)^3$. With respect to the extra-galactic observer the limiting energy is not E_0 because the particle now moves in a combined electric and magnetic field and its kinetic energy is neither E_0 nor is it conserved. The distribution with respect to the extra-galactic observer is of course isotropic. If Swann's suggestion were correct the lower limit of the integral would be indeterminate by the amount $\pm \beta$, since the limiting angle for the limiting energy is infinite because the limiting trajectory is an asymptotic orbit.

FIG. 25.



Angles defined by earth's velocity.

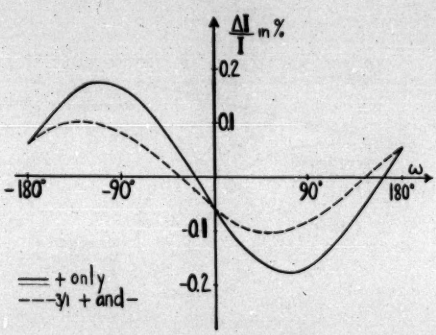
The galactic rotation effect,[24] assuming an inverse cubic distribution function and Oort's value of β (0.001) is shown in Fig. 26, for the vertical direction at the equator. The variation of the vertical intensity is plotted as a function of the hour angle, i.e. of the sidereal time expressed in angular measure. The full curve shows the percentage variation for positive particles alone, the dotted curve for a mixture of positives and negatives in the ratio 3 : 1. The magnitude and phase of the expected effect depend rather strongly on the distribution function of the primaries and also on the percentage of positives and negatives. For equal positives and negatives the amplitude would correspond to the intercept

[24] The details of the calculation will be found in a paper by M. S. Vallarta, C. Graef and S. Kusaka, *Phys. Rev.*, Jan. 1, 1939.

of the dotted curve on the vertical axis. The amplitude of the effect would be changed if the low energy primaries could be filtered off.

We shall now take up briefly the question of the influence of the sun's permanent magnetic field [25] on cosmic ray intensity. Three consequences of the existence of such a field have already been pointed out: the knee of the latitude effect, a diurnal variation of cosmic ray intensity as a function of solar time, and a yearly variation of intensity. While recent high

FIG. 26.



Equatorial galactic rotation effect.

altitude measurements at high geomagnetic latitudes have made the existence of the knee somewhere north of 55° geomagnetic latitude more than probable, in agreement with the expectations of the theory, the present evidence regarding the diurnal and seasonal variations does not seem to favor the hypothesis of the sun's magnetic field. The calculated and observed diurnal variations agree exactly both as regards magnitude and phase at Cheltenham, Maryland, but disagree entirely at Huancayo, Peru. The seasonal variation is apparently of the right magnitude but of the wrong phase, with a maximum in winter and a minimum in summer,

[25] M. S. Vallarta, *Nature*, 139, 839, 1937; L. Jannossy, *Zeits. für Phys.*, 104, 430, 1937.

exactly contrary to expectations. Whether there is here a spurious "temperature effect," already discussed by Compton, which masks the expected effect remains to be seen.

The question of magnetic storms is one of the highest theoretical interest. We have been engaged in examining the possibility that there may be two kinds of current systems associated with such storms: a ring made up of the outermost unstable periodic orbits, mentioned above, which, being unstable, would exist only for a brief time, and a current distribution close to the earth such as already considered by Chapman. Perturbation calculations have already been initiated to find out the influence of such current distributions on the cosmic ray intensity, and while the present indications are that such current distributions are capable of accounting for the existence of magnetic perturbations with and without corresponding changes in cosmic ray intensity, the calculations have not been carried out sufficiently far to warrant a fuller discussion at the present time.

PRESENT STATUS OF THE THEORY OF THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON COSMIC RAYS BY M. S. VALLARTA, Sc.D., Ph.D.

DISCUSSION BY

DR. W. F. G. SWANN.

In discussing the effect of the earth's motion in a region of cosmic-ray intensity which may be regarded as isotropic in some system of axes which we take arbitrarily as at rest, Professor Vallarta has referred to my calculations on this matter, and in particular to the lower limit of energy integration which should be used. It is, of course, in the moving system that the energy of entry is determined, since it is in that system that there is a pure magnetic field. It is only to be expected that the corresponding energy in the resting system, in which system the distribution function is expressed, should depend upon the angle ω, since the relation between the energies in the two systems depends upon this angle. As pointed out in my paper, there is, of course, conservation of energy along a dynamical path in the moving system, but not in the fixed system, since the moving earth functions as an electric as well as a magnetic doublet for the fixed system. Professor Vallarta's difficulty in this matter concerns an apparent ambiguity in the case of the asymptotic orbit which, while encircling the earth an infinite number of times in the moving system, winds itself off to infinity in the fixed system after discontinuing its spiral convolutions. It seems strange to Dr. Vallarta that while some of the spirals are at infinity in the fixed system we should, nevertheless, be required to be careful as to the proper specification of ω. I must admit that I cannot concur in this difficulty because, in spite of some of the convolutions being at infinity in the fixed system, an electron, when in one of those convolutions, was in actuality quite near to the earth, so that the energy to be assigned in the fixed system should depend upon the angle ω, and should vary periodically with this angle. Perhaps it may help the

clarification to realize that in the resting system there are, as it were, two kinds of infinitely distant points in the orbit. There are those which when occupied by the electron are infinitely distant from the sphere, in both the moving system and the fixed system; and there are those which *when occupied by the electron* are never far from the sphere *at the moment of occupation*, either in the fixed or in the moving system. The practical place to assign ω is at the infinitely distant point in the former sense. Even then the lower limit involves ω, because ω determines the point of contact of the orbit with the earth and a potential difference (measured in the fixed system) between this point and infinity varies with the point on account of the influence of the electrostatic doublet to which the earth, as seen in the fixed system, is partially equivalent.

In view of the foregoing considerations, I am unable to acquiesce in Prof. Vallarta's conclusion to the effect that the lower limit which I have taken is erroneous. In Vallarta's formula for I^1, the E_0 refers to the moving system, but the E in $F(E)dE$ is concerned with the extra-galactic fixed system. If the lower limit E_0 is retained, then, in my judgment, $F(E)dE$ should be transformed to an expression in terms of the energy as measured in the moving system.

PRESENT STATUS OF THE THEORY OF THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON COSMIC RAYS BY M. S. VALLARTA, Sc.D., Ph.D.

DISCUSSION BY

DR. T. H. JOHNSON.

Prof. Vallarta has made the point that the longitude effect is a property of the whole distribution function and not just that part of it near the limiting energy. I would like to point out that this interpretation is necessary because Prof. Vallarta has considered a distribution of primary particles with respect to the Lemaitre-Vallarta function r_c and not with respect to energy. The conversion factor for passing from the one distribution to the other is then a function of longitude.

A point of view which makes the matter entirely clear is that presented in my own paper. Here a distribution of primary particles with respect to the energy measured in electron volts has been considered and designated by $j(\epsilon)d\epsilon$. The total intensity is then given by

$$j = \int_{\epsilon_c}^{\infty} j(\epsilon)d\epsilon$$

and is made to depend upon the various geomagnetic variables, including the longitude, through the dependence upon these variables of the lower limit of the integration, ϵ_c. This relation is given by the equation

$$\epsilon_c = 300Mr_c^2/a^2.$$

The longitude effect differs from the latitude and directional effects only in the fact that ϵ_c depends upon the radius of the earth explicitly in the above equation whereas the latitude and direction appear implicitly through the function r_c.

PRESENT STATUS OF THE THEORY OF THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON COSMIC RAYS BY M. S. VALLARTA, Sc.D., Ph.D.

DISCUSSION BY

DR. S. A. KORFF,

Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

The question raised by Professor Vallarta about the longitude effect can probably best be answered by a review of the experimental evidence on this point.

The existence of a longitude effect at sea-level was reported by Clay [1] and independently by Millikan,[2] who estimated that the intensity at Singapore (geomagnetic latitude 0°, geographic longitude 100° E.) was about 4 per cent. below that at Peru (geomagnetic latitude 0°, geographic longitude 75° W.). Airplane flights by Millikan, Korff and Neher,[3] carrying the same electroscopes as used in the sea-level survey [2] to 26,000 feet in the Philippines and to 30,000 feet in Peru, failed to disclose any greater effect up to 26,000 feet. Recently, Millikan and Neher [4] have made balloon flights in Madras, India, geomagnetic latitude 3° N., which may with good approximation be regarded as extensions to a greater altitude of the intensity measurements made in airplane flights in the Philippines (geomagnetic latitude 3° N.).

At the same time, Korff, Curtiss and Astin [5] have made balloon flights in Peru, geomagnetic latitude 1° S. While the latter flights were made using single counters, and all the other measurements were made using electroscopes, good agreement exists between the intensities determined by the counters and by the electroscopes up to the highest altitudes reached by the electroscope flights in Peru, which was about 3 meters of

[1] J. Clay, *Physica*, 1, 829 (1934).

[2] R. A. Millikan and H. V. Neher, *Phys. Rev.*, 47, 206 (1935).

[3] I. S. Bowen, R. A. Millikan, S. A. Korff and H. V. Neher, *Phys. Rev.*, 50, 579–581 (1936).

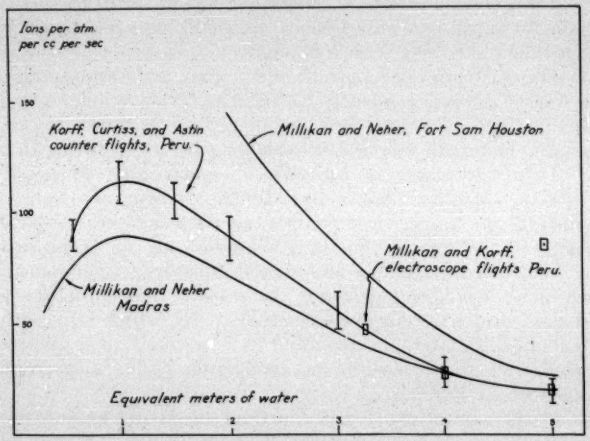
[4] I. S. Bowen, R. A. Millikan and H. V. Neher, *Phys. Rev.*, 53, 217 (1938).

[5] S. A. Korff, L. F. Curtiss and A. V. Astin, *Phys. Rev.*, 53, 14 (1938).

water equivalent below the top of the atmosphere. Therefore, it appears legitimate to consider the counter data as extensions of the electroscope measurements to higher elevations.

Let us compare the electroscope flights in India with the counter flights in Peru, having fitted the counter curves to the Peruvian electroscope flight curve at some point, say at 4 meters of water. The counters then indicate an intensity, at the top of the intensity-altitude curve, of some 25 ± 10

FIG. 1.



Longitude effect between Peru and India, both on the geomagnetic equator.

per cent. greater in Peru than in India. Further, the difference between the intensity at a given elevation in Peru and that at the same elevation in India does not significantly depart from the 4 per cent. sea-level value until an altitude corresponding to 3 meters of water equivalent is reached. Since the flights in the Philippines reached an altitude of only about 3.7 meters of water, it is not to be expected that a large difference between the flights there and in Peru should have been found.

The integral under the curve of ionization as a function of altitude is, for the Peruvian flights, about 16 ± 4 per cent. above that under the curve obtained by Millikan and Neher in Madras. This figure is in good agreement with the value of 15 per cent. computed by T. H. Johnson from an analysis of the distribution-functions of the radiation (see preceding paper by T. H. Johnson).

The intensities at various elevations obtained in India, Peru, the Philippines, and at Fort Sam Houston are shown in Fig. 1. The probable errors of the counter measurements are shown. The other curves are taken from the recent papers by Bowen, Millikan and Neher, cited above.

The conclusion to which this evidence leads is that the longitude effect is about 4 per cent. at sea-level, and remains at about this value up to some 3.5 meters of water equivalent. Above this elevation, the longitude effect increases, finally reaching 25 ± 10 per cent. at an elevation corresponding to 1 meter of water.

Plant Disorders Traced to Unbalanced Diet.—Mysteries that once surrounded many unexplained ailments of plants are gradually giving way before the attacks of science. One by one these plant disorders are being traced to a lack or excess of the so-called minor elements, reported W. O. ROBINSON of the Bureau of Chemistry and Soils, before the fall meeting of the American Chemical Society in Milwaukee. At the turn of the present century only 10 chemical elements were considered necessary for plant growth, Mr. Robinson said. Now we know at least 64 elements are present in soils, and of these 58 have been found in plants of one kind or another. Before much attention was given to the minor elements it was noticed that in many places certain crops gave poor yields and were affected by baffling diseases which are now known as deficiency diseases. Thus it was found that the sand drown of tobacco and a disease of potatoes grown on the highly fertilized potato soils of Maine and the Coastal Plains are due to a deficiency of magnesium. The chlorosis of tomatoes on certain Florida marl soils and gray speck of oats and peas are due to a manganese deficiency. Pecan rosette, citrus mottle leaf and white top of corn are due to zinc deficiencies; and the lack of adequate quantities of boron is responsible for the internal cork of apples, cracked stem of celery heart and dry rot of sugar beet and pathological condition of cauliflower, tobacco, and alfalfa. The use of farm manures, compost, wood ashes, tankage and the like as soil amendments tends to conserve the minor elements in the soil, whereas the use of highly concentrated fertilizers containing only the major plant food elements tends to deplete the soil of the minor elements. This may be the reason that in the long-time fertilizer plot experiments, yields are maintained better by farm manure than by chemical fertilizers. The quantity of minor elements in a given soil may be quite sufficient for the production of a large crop of healthy plants and yet be insufficient to properly nourish the animals feeding upon the plants. The animal must ordinarily have much more sodium and chlorine than plants contain. Since the dawn of history this plant deficiency has been met with by the addition of salt to the ration or diet. The addition of iodine to the diet to correct iodine deficiency appears to be satisfactory. Possibly the same procedure may succeed for cobalt deficiency which apparently causes the 'bush sickness' of sheep in New Zealand, and for other minor elements which are necessary only to animals.

R. H. O.

THE GEOMAGNETIC EFFECTS AND THEIR BEARING UPON THE FUNDAMENTAL PROBLEMS OF THE COSMIC RAY INVESTIGATION.*

BY

THOMAS H. JOHNSON, Ph.D.,

Assistant Director, The Bartol Research Foundation of The Franklin Institute.

This marks about the tenth aniversary of the birth of the corpuscular theory as a useful working hypothesis in our investigation of the cosmic radiation. In 1927 Skobelzyn found high energy electrical particles in the cloud chamber, the Geiger-Mueller tube counter was developed in 1928 and early in 1929 Bothe and Kolhörster used these counters to show that the electrical particles had the same penetrating characteristics as were then attributed to the primary cosmic rays. Up to that time what was known of the cosmic radiation could be summarized by the statement that they consisted of rays of unknown character and unknown energy, produced in unknown parts of the universe by unknown processes and that they were coming into our atmosphere losing most of their intensity by unknown processes of absorption before they reached sea level. During the decade more than six hundred papers reporting investigations of the cosmic radiation have been published and, although the problems suggested by the frequent occurrence of the word "unknown" in the above summary have not all been solved, enough has been learned to increase the interest in this radiation from a meager 14 papers in the year 1929 to well over 100 papers in 1938. Now we know that most of the rays are electrically charged; we know what energies they have; the possibilities for their production have been more closely defined; and some of the processes of energy loss are quite well understood. In this development the geomagnetic effects have played a leading role. The application of Liouville's theorem to the cosmic

*Based upon a paper read at the Chicago Cosmic Ray Symposium, June 29–30, 1938.

ray trajectories, first pointed out by Lemaitre and Vallarta, together with their calculation of the critical energies as a function of latitude and direction, have made it possible to deduce from the observations of the latitude effect and the directional effects what the primary energy distribution is and how the rays are divided between positives and negatives, while balloon flights nearly to the top of the atmosphere in different latitudes have shown how rays of definite energies are absorbed.

SIGNIFICANCE OF INTENSITY MEASUREMENTS.

The theory assigns to each direction in each latitude a definite low energy limit, and the incoming primary radiation for that direction consists of rays in the part of the spectrum above that limit. The intensity observed under the atmosphere is the result of these primaries after they have multiplied by secondary producing processes and have been absorbed by ionization. The intensity actually measured, whether by the electroscope, the counter, or the cloud chamber, is proportional to the number of such primary and secondary rays. In many of the observations the radiation incident from all directions is measured, but by means of Gross's theorem it is possible to transform data of this kind to correspond with what would have been measured if the radiation had been incident from the vertical direction alone. In other cases directionally selective apparatus measures the vertical rays alone, so that it is possible to limit the discussion of the atmospheric effects to the case of vertical incidence.

The curve representing the variation of this intensity with depth has been the subject of many attempted analyses in which justification has been sought for some particular assumptions regarding the absorption and multiplying processes. This problem may be stated in its most general form if we admit that at any depth x the radiation consists of a number of different types of rays designated by subscripts $i, j, \ldots$ such as electrons, photons, barytrons, etc., each of which is characterized by an energy distribution, $j_i(\mathcal{E}_x)d\mathcal{E}_x$ representing the number of rays of type i from unit solid angle per sec per cm.^{2} in the energy range $d\mathcal{E}_x$ at $\mathcal{E}_x$. The distribution in type as well as in energy at any depth x may be considered the out-

growth of a corresponding distribution at some previous depth ξ. The transformation from one distribution to another may be expressed formally by a transformation function of the type $P_j{}^i(\mathcal{E}_x, x - \xi, \mathcal{E}_\xi)d\mathcal{E}_x$ which gives the contribution to the probability of occurrence of a ray of type i at depth x whose energy is in the range $\mathcal{E}_x$ to $\mathcal{E}_x + d\mathcal{E}_x$ by one ray of type j at depth ξ whose energy is $\mathcal{E}_\xi$. The function P depends upon the difference in depth $x - \xi$ and upon the material medium, as well as upon the two types of rays involved in the transformation and their energies. In terms of the P's and j's any observation of the cosmic ray intensity can be related to a corresponding observation at some other depth. Thus the energy distribution of rays of type i at depth x can be expressed by a sum of integrals

$$j_i(\mathcal{E}_x)d\mathcal{E}_x = \sum_j \int_{\mathcal{E}_\xi} j_j(\mathcal{E}_\xi)P_j{}^i(\mathcal{E}_\xi, x - \xi, \mathcal{E}_x)d\mathcal{E}_x d\mathcal{E}_\xi. \qquad (1)$$

The total number of rays of a given type i is given by

$$J_i(x) = \int_{\mathcal{E}_x} j_i(\mathcal{E}_x)d\mathcal{E}_x, \qquad (2)$$

and the total intensity due to all types of rays is

$$J(x) = \sum_i J_i(x) \qquad (3)$$

The energy carried by any one component i is

$$\Phi_i(x) = \int_{\mathcal{E}_x} \mathcal{E}_x j_i(\mathcal{E}_x)d\mathcal{E}_x \qquad (4)$$

and the total energy carried by all rays is

$$\Phi(x) = \sum_i \Phi_i(x). \qquad (5)$$

The object of the analysis of the experimental data is always to find the transformation functions P and the energy distributions at the top of the atmosphere ($\xi = 0$), having given such information as is available regarding the variation of the intensity with depth and with latitude. For this slightly less general case the energy distribution of the ith component at depth x in terms of the distribution of the

primaries is

$$j_i(\mathcal{E}_x)d\mathcal{E}_x = \sum_j \int_{\mathcal{E}_0(\lambda)}^{\infty} j_j(\mathcal{E}_0)P_j{}^i(\mathcal{E}_0, x, \mathcal{E}_x)d\mathcal{E}_0 d\mathcal{E}_x, \qquad (6)$$

where the lower limit in the integration begins at the critical energy defined by the Lemaitre-Vallarta theory. The observational equations of the type (3) and (5) follow immediately from (6) and they relate the quantities measured as intensities with the atmospheric depth, latitude and direction. If one concerns himself with these data alone, his problem is to find the distributions $j_i(\mathcal{E}_0)$ and the diffusion functions $P_i{}^j$ which satisfy the integral equations of the type (3) and (5). I think it is obvious that one cannot hope to find a unique solution, but rather, that there can be an infinite number of solutions to this problem, and it is necessary to resort to other data such as may be obtained by detailed study of the multiplication and ionization processes in the cloud chamber or by application of the theory. The truth of this statement is born out by the numerous solutions already suggested which have taken into consideration only the intensities, and have given a satisfactory agreement with the facts.

Although the equations (3) and (5) do not admit of a unique solution it nevertheless reamins true that any suggested solution arising from fundamental theory or cloud chamber studies must satisfy these equations. It can be shown for example that the assumption of a single component of range particles, i.e. particles for which higher energies penetrate to greater depths, cannot be a satisfactory solution. Inasmuch as the absorption of the penetrating component seems to be like that of a range particle, and inasmuch as most of the sea level intensity and, *a fortiori*, that below sea level is due to this component, an argument can be made on this basis to show that the penetrating rays must be secondaries produced in the atmosphere. Let us assume that the penetrating rays are primaries, absorbed as range particles. The range-energy relation for these particles has been determined by Blackett [1] from the energy distribution observed in the cloud chamber and the range distribution obtained from the intensity vs. depth curve below sea level. This relation may be represented by $R(\mathcal{E})$ and the inverse relation by $\mathcal{E}(R)$. With a single component the summation in equation (6) may be omitted, and for range particles the integral of P over the energies at depth x, indicated in equation (2), has the value unity if x is less than $R(\mathcal{E}_0)$ and zero if x is greater than $R(\mathcal{E}_0)$, where $\mathcal{E}_0$ refers to the energy of the particle at the top of the atmosphere. In high latitudes where the energy $\mathcal{E}(10)$ required to penetrate ten meters through the atmosphere is greater than the energy $\mathcal{E}(\lambda)$ required to pass

[1] P. M. S. Blackett, *Proc. Roy. Soc.*, **159A**, 19 (1937).

through the earth's field at latitude λ, the intensity below sea level is given by

$$J(x) = \int_{\mathcal{E}(x)}^{\infty} j(\mathcal{E}_0) d\mathcal{E}_0, \tag{7}$$

whereas in low latitudes the sea level intensity is given by

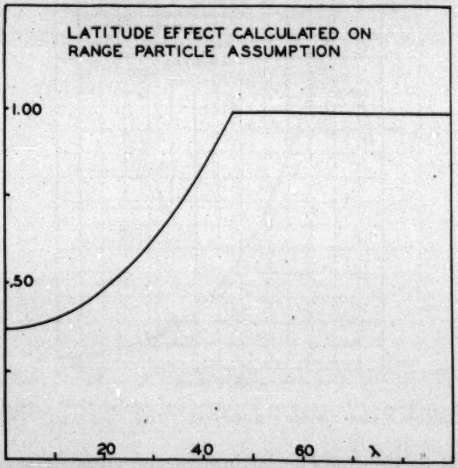
$$J_{10}(\lambda) = \int_{\mathcal{E}(\lambda)}^{\infty} j(\mathcal{E}_0) d\mathcal{E}_0. \tag{8}$$

It follows from the similarity of these two expressions, that the intensity at sea level at latitude λ must equal the intensity in high latitudes at depth x, where λ and x are related by the equation

$$\mathcal{E}(\lambda) = \mathcal{E}(x). \tag{9}$$

We know $\mathcal{E}(\lambda)$ from the Lemaitre-Vallarta theory and $\mathcal{E}(x)$ is given by Blackett's range-energy relation. Hence it is possible to construct a curve for the predicted latitude effect from the variation of intensity with depth. Such a curve is shown in Fig. 1 and the total predicted latitude effect is many times the value actually

FIG. 1.



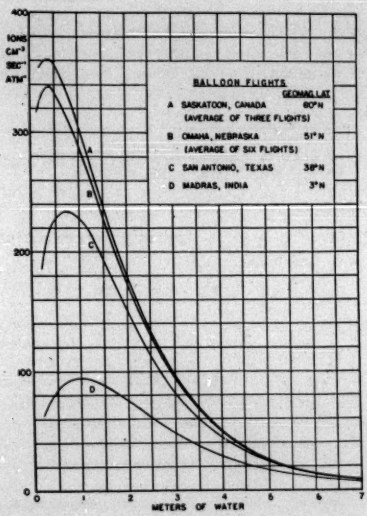
The latitude effect calculated from the observed intensity depth curve in high latitudes on the assumption that the penetrating component consists of primary range particles. The sixty per cent. variation of intensity with latitude compared with an observed ten per cent. can be used as an argument that the penetrating rays are secondary to higher energy primaries.

found. However the position of the knee is in approximate agreement with that found from the sea level measurements. It seems probable that the source of this discrepancy is in our assumption that the penetrating rays at sea level are the primary particles, and this constitutes an argument for the secondary character of this component.

ANALYSIS OF THE PRIMARY COSMIC RADIATION.

For the analysis of the primary energy distribution it is impossible to make measurements of the intensity so close to the top of the atmosphere that an appreciable multiplication has not already set in and an extrapolation of the intensity depth curve to zero depth is exceedingly uncertain because of the shape of the curve in this region. A more satisfactory

FIG. 2.



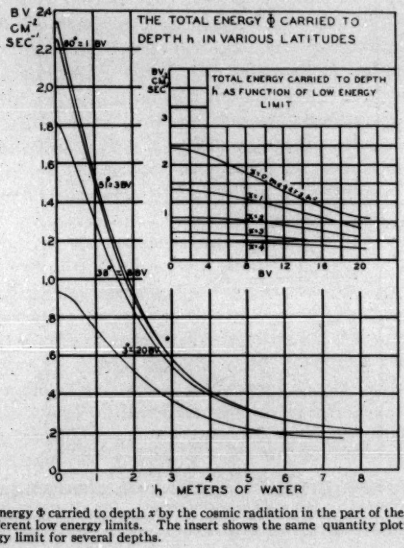
Experimental values of the cosmic ray intensity in four latitudes plotted as a function of the atmospheric depth in equivalent meters of water. Bowen, Millikan and Neher (*Physical Review*).

approach to the problem is through the curves representing the total energy carried to depth x as a function of x at different latitudes. By far the best data for this purpose are those obtained by Bowen, Millikan and Neher [2] in a series of balloon flights made in latitudes 3° N., 38° N., 51° N. and 60° N., where the minimum energies allowed by the earth's

[2] Bowen, Millikan and Neher, *Phys. Rev.*, **53**, 855 (1938).

field range from 1 BV[3] to about 19 BV. These data are reproduced in Fig. 2, and they represent the intensities measured as a function of depth for each of the four latitudes. The integral under a given curve from depth x to infinity gives the total number of ions produced by all of the rays which reach depth x, and if we multiply this number by 32 volts (the average energy required to produce one ion pair), the

FIG. 3.


THE TOTAL ENERGY Φ CARRIED TO DEPTH h IN VARIOUS LATITUDES
TOTAL ENERGY CARRIED TO DEPTH h AS FUNCTION OF LOW ENERGY LIMIT
BV
h METERS OF WATER

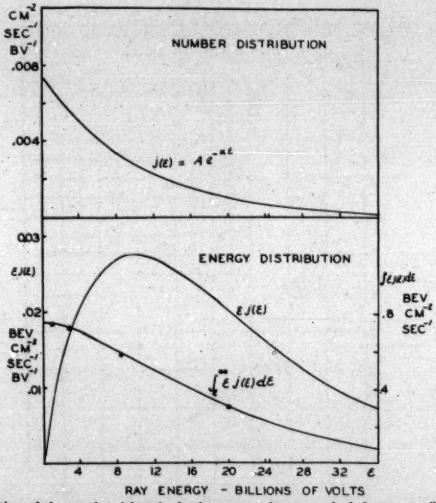
The total energy Φ carried to depth x by the cosmic radiation in the part of the spectrum above each of four different low energy limits. The insert shows the same quantity plotted as a function of the low energy limit for several depths.

result is the total energy expended, and hence the total energy carried, by rays which reach the depth x. The result of an analysis of this kind is shown in Fig. 3 where the energy Φ carried to depth x is plotted in units of billion electron volts per cm.^{2} per sec. against atmospheric depth in equivalent meters of water. The insert gives the same data but here

[3] BV stands for 10^9 electron volts.

the energy carried to a given depth is plotted against the minimum energy admitted by the earth's field. The derivatives of Φ with respect to the energy, i.e. the slopes of the curves in the inset, give the energies carried by primaries in unit range of energy and this could be determined for each energy. However each of these curves have been constructed from only four points so that the derivative is not well defined

FIG. 4.



Distribution of the number (above) of primary cosmic rays and of the energy (below) carries by these rays plotted as a function of the individual energies. One of the lower curves representd the energy carried by primary rays in unit range of the spectrum, while the other is the energy carried by all rays whose individual energies exceed the value plotted as abscissa.

by the data. Therefore the reverse procedure has been adopted of seeking a distribution function of the primary rays which gives the extrapolated energies for zero depth. A distribution which fits the data for the four latitudes is shown in Fig. 4. The distribution in number is given by

$$j(\mathcal{E}) = A \exp.(-\alpha\mathcal{E}) \text{ with } A = .0075 \text{ primary rays} \quad (10)$$

per cm.^{2} per sec. per billion volt range of energy and from unit

solid angle, and $\alpha = .1\ \mathrm{BV}^{-1}$. The total energy carried by rays of energy greater than $\mathcal{E}$ is

$$\Phi(\mathcal{E}) = \int_{\mathcal{E}}^{\infty} \mathcal{E} j(\mathcal{E}) d\mathcal{E} = (\mathcal{E} + 1/\alpha) j(\mathcal{E})/\alpha \qquad (11)$$

and the energy carried by rays of energy $\mathcal{E}$ to $\mathcal{E} + d\mathcal{E}$ is

$$\mathcal{E} j(\mathcal{E}) = \mathcal{E} A e^{-\alpha \mathcal{E}}. \qquad (12)$$

These two functions are also plotted in Fig. 4. The test of this distribution is that $\Phi(\mathcal{E})$ shall agree with the energies computed from the observed intensities. For the higher latitudes where the range of energies which only partially illuminate the earth's surface is small, the value of Φ for the limiting energy in the vertical direction should agree with the observed value, but at the equator it is necessary to compute the energy more rigorously. The Lemaitre-Vallarta theory tells us what fraction of the sky is illuminated by each energy and so, having given an energy distribution of primary rays, it is possible to compute the total incident energy by integrating the contributions from rays of each energy. The distribution cited above has been adjusted so that a rigorous integration of this type gives the observed energy at the equator. It is an interesting observation that this energy is the same as would be incident if rays of energy greater than 20 BV were isotropic and all rays of lower energy were absent. The effective minimum energy is therefore somewhat higher than the cut off limit for the vertical direction, the latter being 18 BV.

In view of the interesting proposal of Vallarta and Janossy that the cosmic ray spectrum should have a low energy limit if the sun's magnetic field is sufficient to exclude some of the low energy rays from the earth's orbit the above analysis of the balloon flight curves presents some interesting points. In the first place the falling off at low energies of the curve representing $\mathcal{E} j(\mathcal{E})$ is evidently due to the fact that the energy carried by rays of low individual energies is necessarily low unless the number of these rays is infinitely large. The position of the maximum is an important property of the distribution function but it cannot be interpreted as indicating a maximum in the distribution of the number of primaries. In the second place the total incident energy levels

off in a natural way at the low energy end of the curve and it would require experiments of very great accuracy to distinguish between a distribution function of the type chosen here, for example, and one in which there are no rays of energy less than about 2 BV. Reference to curves in the inset of Fig. 3 also shows that the possibility of making such a distinction diminishes very rapidly with increasing depth.

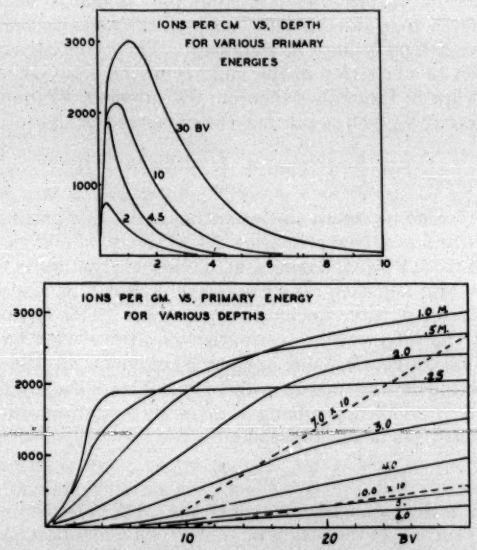
ABSORPTION AND MULTIPLICATION OF ONE PRIMARY RAY.

The difference between the ordinates of any two of the curves of Fig. 2 represents the intensity at the corresponding depth produced by all rays whose energies lie between the low energy limits defined by the theory for the two latitudes in question. On the other hand the distribution of the number of primary rays with respect to their individual energies, given by $j(\delta)$, tells us how many primary rays have been instrumental in producing that intensity. Thus it is only necessary to divide one of these numbers by the other in order to find what intensity at each depth is produced by one primary ray. This analysis has been made for four different primary energies and the intensities are plotted against depth in the atmosphere in the upper diagram of Fig. 5. Here the ordinates represent the number of ions per vertical cm. produced at various depths by one primary ray and all of its secondaries. The curve for 30 BV has been derived from the intensity measured at the equator on the assumption that this also results from electrically charged primaries characterized by the energy distribution given by equation (10). It is an interesting fact that this curve is similar to those corresponding to the lower energies and it represents a natural extension of those curves to the higher energy. We thus encounter no anomalous behaviour of this radiation if we assume that it is also electrically charged and that it differs from the balance of the radiation only in respect to its higher energy.

The lower diagram of Fig. 5 again represents the number of ions per cm. produced by one primary ray but in this case it is plotted for various depths as a function of the energy of the primary ray. It is interesting to observe that the multiplication at a quarter of a meter depth is practically the same for rays of all energies greater than 4 BV but at the greater

depths the higher energies show the greater multiplication. The data for 7 meters and ten meters, are plotted in the dotted curve to a scale ten times that used for the other curves. The ten meter data have been obtained from Compton and Turner's measurements on the Pacific Ocean.

FIG. 5.



The number of ions per vertical centimeter produced by one primary cosmic ray. In the upper diagram this quantity is plotted for various energies as a function of the depth, and in the lower diagram it is plotted as a function of the energy for several depths. The results have not been reduced to vertical incidence. Without any multiplication a ray produces, on the average, 200 ions per cm. of path. Division of the ordinates by this figure gives, approximately, the amount of multiplication at various depths.

EVIDENCE FROM THE GEOMAGNETIC EFFECTS AT SEA LEVEL BEARING UPON THE NATURE OF THE PRIMARY RADIATION.

The east-west asymmetry can be ascribed to the excess of the intensity produced by primary positives above that produced at the same depth by primary negatives, the rays referred to being those whose energies lie between the low energy limits for the eastern and western directions. All of

the other geomagnetic effects, i.e. the latitude effect, the north-south asymmetry, the longitude effect and the magnetic storm effect depend upon the sum of the intensities produced by both positives and negatives. Hence by combining the magnitude of the east-west effect with that of any of the other effects it is possible to determine what part of the intensity at the given depth is due to positives and what part is due to negatives. In this way four independent values of the ratio of positive to negative intensity may be obtained. Their consistency may be taken as a criterion of the validity of the analysis.

In view of Liouville's theorem the intensity of the cosmic radiation at a given depth may be expressed in the form

$$j = \int_{\mathcal{E}_c^+}^{\infty} j^+(\mathcal{E})d\mathcal{E} + \int_{\mathcal{E}_c^-}^{\infty} j^-(\mathcal{E})d\mathcal{E} + K, \qquad (13)$$

where $j^{\pm}(\mathcal{E})d\mathcal{E}$ represent the intensities at depth x produced by positive and negative primaries, respectively, of energy in the range $\mathcal{E}$ to $\mathcal{E} + d\mathcal{E}$, $\mathcal{E}_c^{\pm}$ represent the low energy limits for the positive and negative rays respectively, and K is inserted to take care of possible uncharged primaries. This representation of the intensity brings in the variations with latitude, direction, longitude, and magnetic moment of the earth through the dependence upon these variables of the low energy limits, $\mathcal{E}_c^{\pm}$. This dependency is given by a relation which, for high energy particles, approximates to

$$\mathcal{E}_c^{\pm} = 300 M r_c^{\pm 2}/a^2. \qquad (14)$$

Here M is the magnetic moment of the earth, a is the distance from its surface to the magnetic center, conveniently called the magnetic radius, and $r_c^{\pm}$ are the Lemaitre-Vallarta functions of latitude and direction for the positive and negative rays respectively. These are pure numbers, ranging from zero to one. Except for the vertical direction the dependence of intensity upon zenith angle ζ involves an atmospheric effect and to avoid this it will be convenient to limit the discussion to the geomagnetic effects of the vertical rays alone. This brings about an additional simplification since for this direction

$$r_c^+ = r_c^-; \qquad [dr_c^+/d\zeta]_{EW} = -[dr_c^-/d\zeta]_{EW};$$
$$[dr_c^+/d\zeta]_{NS} = [dr_c^-/d\zeta]_{NS}$$

and we may write simply r_c when refering to r_c^+ and use the negative sign appropriately with the same symbol when refering to r_c^-. With these simplifications the five geomagnetic effects in the vertical direction may be expressed in differential form by taking the logarithmic derivative of equation (13) with respect to each of the variables. The expressions obtained in this way are the following:

I. The Latitude Effect.

$$\partial j/j\partial\lambda = -(600M/ja^2)[j^+(\mathcal{E}_c) + j^-(\mathcal{E}_c)]r_c\partial r_c/\partial\lambda. \quad (15)$$

II. The East-West Effect.

$$[\partial j/j\partial\zeta]_{EW} = -(600M/ja^2)[j^+(\mathcal{E}_c) - j^-(\mathcal{E}_c)]r_c[\partial r_c/\partial\zeta]_{EW} \quad (16)$$

III. The North-South Effect.

$$[\partial j/j\partial\zeta]_{NS} = -(600M/ja^2)[j^+(\mathcal{E}_c) + j^-(\mathcal{E}_c)]r_c[\partial r_c/\partial\zeta]_{NS}. \quad (17)$$

IV. The Longitude or Radius Effect.

$$a\partial j/jda = (600M/ja^2)[j^+(\mathcal{E}_c) + j^-(\mathcal{E}_c)]r_c^2. \quad (18)$$

V. The Magnetic Moment Effect.

$$Mdj/jdM = -(300Mr_c^2/ja^2)[j^+(\mathcal{E}_c) + j^-(\mathcal{E}_c)]. \quad (19)$$

The relative numbers of positives and negatives can be most conveniently expressed by the quantity β defined by

$$\beta(\mathcal{E}) = [j^+(\mathcal{E}) + j^-(\mathcal{E})]/[j^+(\mathcal{E}) - j^-(\mathcal{E})].$$

Dividing equation (16) by each of the others in the above series the following expressions for β are easily obtained. These are designated according to which equation was used as the quotient.

I. Latitude Effect.

$$\beta_\lambda = [(\partial j/j\partial\lambda)/(\partial j/j\partial\zeta)_{EW}][(\partial r_c/\partial\zeta)_{EW}/(\partial r_c/\partial\lambda)]. \quad (21)$$

II. North-South Effect.

$$\beta_{NS} = [(\partial j/j\partial\zeta)_{NS}/(\partial j/j\partial\zeta)_{EW}][(\partial r_c/\partial\zeta)_{EW}/(\partial r_c/\partial\zeta)_{NS}]. \quad (22)$$

III. Radius Effect.

$$\beta_a = -[(a\partial j/j\partial a)/(\partial j/j\partial\zeta)_{EW}][(\partial r_c/\partial\zeta)_{EW}/r_c]. \quad (23)$$

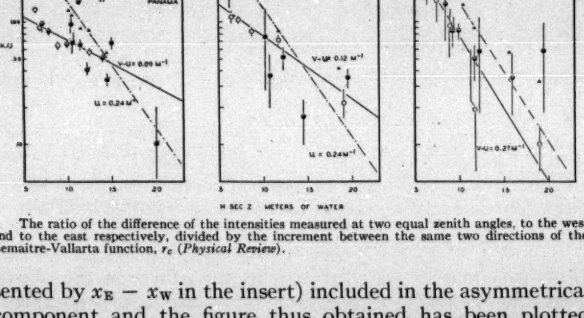
IV. Magnetic Moment Effect.

$$\beta_M = [(M\partial j/j\partial M)/(\partial j/j\partial\zeta)_{EW}][2(\partial r_c/\partial\zeta)_{EW}/r_c]. \quad (24)$$

The quantities involved here are the values of r_c and of its derivatives, which have been computed by Lemaitre and Vallarta,[2] and the differential geomagnetic effects for which we have observational data at sea level and at certain other accessible depths.

Figure 6 represents[4] all of the available data, for all elevations and zenith angles, of the magnitude of the east-west asymmetry, grouped under three latitudes. The experimental values have been divided by the range of r_c (repre-

FIG. 6.



The ratio of the difference of the intensities measured at two equal zenith angles, to the west and to the east respectively, divided by the increment between the same two directions of the Lemaitre-Vallarta function, r_c (*Physical Review*).

sented by $x_E - x_W$ in the insert) included in the asymmetrical component and the figure thus obtained has been plotted logarithmically against the atmospheric depth. The various points fall more or less along a straight line and from the dispersion of the points it is possible to estimate the probable limits of error. The quantity plotted is equal to the ratio $(\partial j/j\partial\zeta)_{EW}/(\partial r_c/\partial\zeta)_{EW}$ appearing in each of the equations (21) to (24). Values for this ratio which may be read from the diagram of Fig. 6 are listed in Table I, column 1.

The best available data for the latitude effect have been obtained by Compton and Turner[5] on the Pacific Ocean. In this work they have used a spherical ionization chamber

[4] T. H. Johnson, *Phys. Rev.*, **48**, 287 (1935).

[5] A. H. Compton and R. N. Turner, *Phys. Rev.*, **52**, 799 (1937).

TABLE I.

Values of the Quantities Entering into Equations (21) to (24) for the Determination of β and the Values of β thus Determined.

	1	2	3	4	5
	$\frac{[\partial j/\partial\zeta]_{EW}}{[\partial r_c/\partial\zeta]_{EW}}\cdot\frac{[\partial j/\partial\zeta]_{NS}}{[\partial r_c/\partial\zeta]_{NS}}$	$\frac{\partial j/j\partial\lambda}{\partial r_c/\partial\lambda}$	$\frac{a\partial j/j\partial a}{r_c}$	$\frac{M\partial j/j\partial M}{r_c}$
$\lambda=0°$ $x=10$ m.	$.70\pm.10$			3.2 ($\beta_a=4.6$)	120 ($\beta_M=170$)
$\lambda=30°$ $x=10$ m.	$.75\pm.20$		$.87\pm.3$ ($\beta_\lambda=1.16\pm.5$)		
$\lambda=30°$ $x=6$ m.	$1.3\ \pm.2$	$1.0\pm.3$ ($\beta_{NS}=.8\pm.3$)			

shielded with 12 cms. of lead. It is therefore necessary to transform their results by a Gross transformation in order to obtain the latitude effect for the vertical radiation. According to a statement of Millikan and Neher no correction need be applied because of the lead shield for they have found no relative differences in the latitude effects with and without similar shields. If we represent the intensity from all directions by J and that from the vertical by j Gross's theorem gives the relation

$$j(\lambda) = G(\lambda)J(\lambda)/2\pi, \tag{25}$$

where the Gross factor $G(\lambda)$ is $G(\lambda) = 1 - h\partial J/J\partial h$, h representing the vertical depth in the atmosphere. Differentiating with respect to λ

$$\partial j/j\partial\lambda = \partial G/G\partial\lambda + \partial J/J\partial\lambda. \tag{26}$$

The variation of J, is accurately determinable from the results of Compton and Turner; for $\lambda = 30°$ the slope of their mean curve gives $\partial J/J\partial\lambda = .0033$ per degree. The situation with regard to the variation of G with respect to latitude is not as favorable, and it is necessary to resort to the less accurate data obtained by A. H. Compton [6] in his original world survey. A semi logarithmic plot of his data showing the variation of

[6] A. H. Compton, *Phys. Rev.*, **43**, 387 (1933).

intensity with depth at the equator and at high latitudes was constructed and from the best straight line drawn through the points near sea level the values $G = 3.35$ for the equator and $G = 3.60$ for high latitudes were obtained. These values are nearly proportional to the sea level intensities at the corresponding latitudes and it seems reasonable to assume that this proportionality holds throughout. Thus we may write $G = \text{constant} \cdot J$ and

$$\partial j/j\partial\lambda = 2\partial J/J\partial\lambda. \qquad (27)$$

It is noted that a factor of two for the difference of the latitude effects of vertical and of the total radiation is also indicated by the results of Johnson and Read [7] who have measured the latitude effect for the vertical radiation. Unfortunately their data were obtained for the voyage through the Panama Canal where anomalies, probably due to local magnetic disturbances, seem to be in evidence, and they are not suitable for an analysis based upon the Lemaitre-Vallarta functions which pertain to the field of a dipole. The final value of the latitude effect for $\lambda = 30°$ is listed in the Table I. Its principle uncertainty is due to the G factor and this has been estimated at thirty per cent. The value of β_λ obtained by combining the latitude effect with the east-west asymmetry is also listed in the table together with an estimate of its uncertainty.*

A value for β of comparable accuracy may be obtained from the north-south effect. This was measured with some precision in the latitude of 30° at an atmospheric depth of 6 meters, and from the points for small zenith angles, combined with the Lemaitre-Vallarta values for the energy differences between the north and south directions in the meridian plane one obtains the values cited in the second column of the table.

From the longitude effect one may obtain a third value of β but here there seems to be an anomalous situation whose explanation is not yet clear. From Vallarta's [8] compilation of the data there appears to be a four per cent. amplitude in

[7] T. H. Johnson and D. N. Read, *Phys. Rev.*, **51**, 557 (1937).

* A better analysis of the sea level geomagnetic effects leading to substantially the same conclusions was made after the presentation of this paper and is published in *Rev. Mod. Physics* October, 1938.

[8] M. S. Vallarta, *Phys. Rev.*, **47**, 647 (1935).

the variation of the cosmic ray intensity along the equator, whereas the magnetic radius undergoes a variation of five per cent. Doubling the former figure, for reduction to the vertical, and dividing by the latter and the value .5 of r_c. one obtains the results listed in the fourth column of Table I. The value of β_a is about four times that found by the other two methods. Added to this numerical discrepancy is a disagreement in the phase of the longitude effect with that predicted by the theory, for the minimum found for the cosmic ray intensity occurs about 80° to the west of the position of minimum magnetic radius. The experimental points are few in number and it is possible that the variations of cosmic ray intensity with time may be responsible for this seeming inconsistency between the data and the theory.

The magnetic moment effect has been considered to be the cause of the variations of cosmic ray intensity during magnetic storms. In a typical storm reported by Forbush a 2.5 per cent. change of cosmic ray intensity was accompanied by a change in the magnetic field at the equator of 0.25 per cent. If we take into account the currents induced in the earth according to a suggestion of Chapman,[9] and assume that the currents producing the magnetic effects are located above the earth but within a distance small compared with the earth's radius, the effect cited leads to a value of the coefficient $Mdj/jdM = -60$ and this corresponds to a value of β_M equal to 170. It is necessary to conclude that this interpretation of the magnetic storm effect is entirely inconsistent with the other geomagnetic effects from which one obtains $\beta \doteqdot 1$.

The two most reliable determinations of β lead to values of the order of unity. The other determinations differ from these by such large amounts that one has to resort to other explanations of the effects upon which they are based. A value of $\beta = 1$ means that all of the primaries are positive, $\beta = 1.5$ would mean a sixteen per cent. negative component, and of course values of β less than one are impossible. We are thus led to conclude that *most, if not all, of the primary rays which produce the geomagnetic effects at sea level in intermediate latitudes are positive.*

[9] S. Chapman, *Nature*, 140, 423 (1937).

It is now realized that there are two components of the cosmic radiation, the penetrating rays and the soft rays. The penetrating rays are absorbed by various substances in proportion to the amount of mass, they do not produce showers, and they seem to consist of heavy electrons, or barytrons. It has been estimated that about eighty per cent. of the intensity at sea level is produced by these rays. Arguments similar to the one given in the first part of this paper, based upon the energy-range relation and the relation of the latitude effect to the ionization depth curve, indicate that most if not all of the penetrating rays are secondaries generated in the atmosphere by primary rays of considerably higher energies.[10] The soft component produces showers; it is absorbed in various substances in proportion to Z^2; it produces most of the intensity at the top of the atmosphere but less than twenty per cent. of it at sea level. From the initial form of the ionization depth curve it is reasonable to conclude that these rays are primaries, and the latitude effect of the total energy indicates that they are practically all electrically charged.

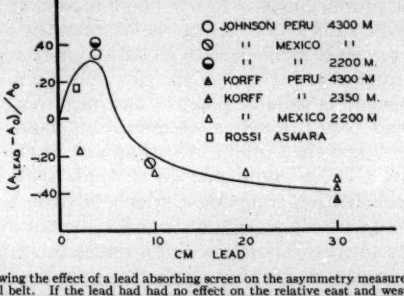
In regard to the electrical properties of the primaries which produce the penetrating rays, the argument is less conclusive, for the sea level geomagnetic effects might have been caused by the penetrating component or they might have been due to what remains at sea level of the soft component. In fact the increase of the asymmetry and latitude effects with elevation seemed to indicate that the latter view was correct in spite of the fact that most of the sea level intensity was produced by the penetrating rays. There are however several reasons for adopting the opposite point of view, to wit, that the sea level latitude and asymmetry effects are properties of the penetrating component and therefore its primary radiation is also electrically charged. In the first place, as has been emphasized by Millikan and Neher [11] the latitude effect at sea level is practically independent of the thickness of the lead shield placed over the electroscope. If the latitude effect were due to the soft component it would have been almost entirely

[10] Another form of this argument has been given by Nordheim, *Phys. Rev.*, 53, 694 (1938).

[11] Millikan and Neher, *Phys. Rev.*, 50, 15 (1936).

screened off from the electroscope by the 12 cm. shields of lead which have been used. In the second place, studies of the asymmetry in the equatorial belt with lead placed above and between the coincidence counters have shown even a slight increase in the asymmetry with the lead as compared with its value without the lead. These results are shown in Fig. 7.[12] The slight increase in the asymmetry for the first thicknesses of lead might have been due to the elimination of the soft diffused rays or it might mean that the soft component rays cut out by the lead are not asymmetric. The

FIG. 7.



Results showing the effect of a lead absorbing screen on the asymmetry measured near sea level in the equatorial belt. If the lead had had no effect on the relative east and west intensities the curve would have had the constant value 0. Complete absorption of the asymmetrical component, to be expected if they belong to the soft component, would have dropped the curve to −1.00. The relatively small effect found is taken as evidence that the asymmetry is a property of the penetrating component (*Physical Review*).

latter interpretation is preferred in view of the results of some other experiments in which the asymmetry of the shower producing radiation was measured.[13] In the experiments referred to practically no asymmetry was found, indicating that the primary soft rays are either equally positive and negative or, that the soft rays which get to sea level are of such high energy that they are not effected by the earth's field. In either case their elimination by the lead in the former experiments would have increased the asymmetry. The values of the asymmetry for greater thicknesses of lead,

[12] T. H. Johnson, *Phys. Rev.*, **48**, 287 (1935).
[13] T. H. Johnson, *Phys. Rev.*, **47**, 318 (1935).

shown in Fig. 7, fell below the asymmetry without lead but the rate of decrease with lead thickness follows closely to what one expects of the penetrating component. A third argument in favor of the asymmetry of the penetrating component is found in the persistence of the asymmetry to zenith angles of more than sixty degrees, where the effective atmospheric path exceeds twenty meters. At these depths whatever soft rays remain must be entirely a secondary product of the penetrating rays. These arguments tend to overbalance the evidence favoring the soft component, i.e. those based upon the increase of asymmetry and latitude effect with elevation, especially when it is realized that the asymmetry is due to only the primary rays of lowest energies, and that this fact alone may be sufficient to make the asymmetric penetrating rays near sea level increase with elevation more rapidly than the total intensity. If this is the case, however, and if the soft component is equally positive and negative, the asymmetry would pass through a maximum at about five or six meters depth and then practically disappear at the top of the atmosphere. These arguments go to show that it may be only the penetrating component which has the asymmetric property and we need attribute the preponderance of positive charge only to the primaries which produce this component.

An excess of one sign of charge in the primary radiation as it exists in intergalactic space must be considered extremely doubtful. Swann [14] has called attention to the large potential differences which would exist in comparatively small distances if any appreciable fraction of the cosmic rays were unneutralized by opposite charges, and the more recent evidence as to the total number of cosmic rays in space leads to a figure of $7.10^{18} R^2$ volts, where R is the distance measured in light years, if all of the rays are of one sign. We must therefore limit our hypotheses as to the nature of the primary radiation to those in which equal numbers of positive and negative rays are moving through space with equal velocities. Gunn [15] has pointed out that if ions of one sign of charge are being projected into space from some stellar atmosphere the electro-

[14] W. F. G. Swann, *Phys. Rev.*, 44, 124 (1933).
[15] R. Gunn, *Terr. Mag.*, 38, 247 (1933).

static attraction of its space charge would propel charges of the opposite sign in the same direction until they had attained the velocity of the ion beam. Gunn has also pointed out what the effect of the earth's magnetic field would be upon such a neutralized ion beam. The energies and the momenta of the particles having the two signs of charge will be proportional to the respective rest masses. Hence the heavier particles could succeed in reaching the earth's surface while the lighter particles would be turned back. In the case of a beam of protons neutralized by negative electrons, only positive rays would be detected near the equator.

SUMMARY.

Summarizing the evidence as to the nature of the primary cosmic radiation the following points stand out.

(1) The Balloon flight data of Bowen, Millikan and Neher show that the soft component is practically one hundred per cent. electrically charged. As far as the asymmetry experiments go these rays are equally positive and negative though this point is not well established.

(2) The penetrating component which seems to consist of equal numbers of positive and negative heavy electrons, is secondary to primary rays of higher energy. These primaries are, within experimental error, entirely positive.

(3) The radiation in external space must be electrically neutral. Hence it is sufficient to assume that the positive primaries of the penetrating component are more massive than the negative rays which neutralize them. A most reasonable assumption would be that this component consists of protons or heavier ions, neutralized by free electrons.

The completely electrical character of the primary radiation (the absence of photons and neutrons) gives some basis for hypotheses regarding their origin. If the radiation has passed through a stellar atmosphere before reaching the earth of even a fraction of a meter of water equivalent it would have generated a large number of neutral rays. The absence of such rays leads us to suppose either (*a*) that the rays have been generated in vacuous space or (*b*) that the electrically charged particles have been detained in this region of space by a galactic magnetic field, whereas the neutral rays have passed

freely out. Because of the difficulty of envisaging mechanisms for the production of rays in vacuous space the latter hypothesis seems preferable. The degree to which an equilibrium with matter has been reached will then have to be inferred from the proportion of soft and penetrating rays in the primary beam.

The view developed here as to the nature of the primary radiation invokes the production of heavy electrons when high energy protons collide with matter. Whether or not this is a welcomed suggestion must be left to the theorist to decide.

PROGRESS OF THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE *

BY

DR. ELLICE McDONALD,

Director.

This is the third annual report of progress of the Foundation which has gone forward during the past year with development in knowledge and in methods. We have had our successes and our disheartenings, but such is the quality of research effort that successes cannot be commanded. However, we can see the future and believe as Dr. Kettering has recently said, "I think you will see perfectly astounding development in biochemistry. Medicine has had a hard time and is just beginning to use the physicist and the chemist through no fault of the doctors. We are in a transition period between individual invention and group invention."

In our research laboratories, the effort has been to maintain the individuality of the worker and at the same time orient him in a coöperative group where the best efforts of all are brought out. This effort, not easy, requires training, tact and aptitude. It is not every worker who is so constituted as to be able to work in a group. It is disturbing to some. They may have to be gradually educated as to the advantages to their research and to their development of the help and criticism of other scientists and often such as seem to be quite remote from their own fields. Group conferences often bring out entirely new aspects of a problem and often suggest entirely new phases or new problems as a result of bringing a number of minds to bear on a single project.

In this, the incidental suggestion or the accidental discovery should by no means be neglected. Often the by-product is of more importance than the stated effort. If research laboratories could be blessed with *serendipity*, their lot would be happy. This strange word was coined by

* Presented at the Stated Meeting held Wednesday, December 21, 1938.

Horace Walpole in 1754 and the new Oxford dictionary gives its meaning as "the faculty of making happy and unexpected discoveries by accident." Fortunate indeed is the laboratory which has serendipity. But discovery comes to the prepared mind, so that serendipity may be cultivated for the mind is but a barren soil and soon exhausted unless it be continually enriched with new ideas and new aspects of old ideas. This is the hope of group research.

A realization of the urgent need for medical and biochemical research makes no call on the imagination and requires no special medical knowledge. We have all seen pain and death at close enough quarters to wish that we were better armed against them; and it is evident that the only effective forces we can hope for are those fashioned by science. The general public do not realize that the case for extended research in biochemistry is stronger than ever before because the prospects are brighter. Each new discovery brings other discoveries nearer, so that the potential rate of advance continuously increases. One discovery is the surety for more.

In order to have our laboratories in the best possible situation for research discovery, frequent readjustments are required although none of these is violent. In groups, marshalling of the forces to present the best front is necessary.

For this reason we have within the last year reassembled our groups to establish a new department of Physical Chemistry since there has grown up a series of phases of biochemical research of great importance in this field and these require special treatment.

All our efforts are towards what Benjamin Franklin called "useful knowledge," but the ideal cannot be immediately achieved in most cases, because a considerable amount of fundamental research must first be done in order to establish principles and criteria before advancing to application. This is the only way to avoid the pitfalls of the practical effort when not regulated by scientific criteria.

The establishment of the Department of Physical Chemistry is in line with this and really involves the mixture of fundamental research and practical application on the basis of control and knowledge contributed by fundamental research.

THE PHYSICAL CHEMISTRY DEPARTMENT.

The physical chemistry department has been formed only recently. However, the group composing this department has been working together under a chairman since the time of the last annual report. The main project on which the group is united is an outgrowth of ultracentrifuge studies on immune blood sera. It has been found that by a special technique diphtheria antitoxin and antipneumococcus antibody can be concentrated and purified.

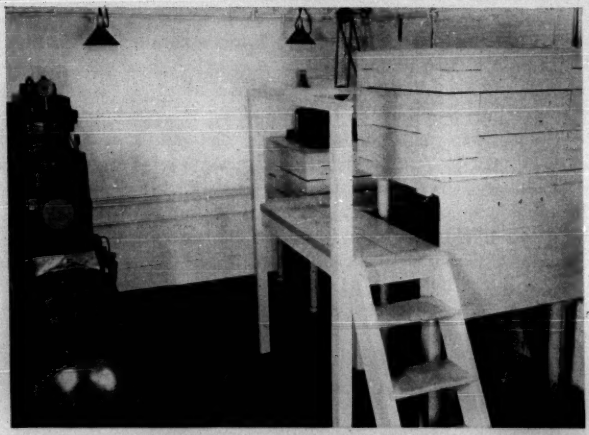
The concentration and purification of antibody by means of the ultracentrifuge is not a new idea, strictly speaking. Wyckoff (*Science*, **84**: 291, 1936) has been able to concentrate antibody from antipneumococcus horse serum but the method is not applicable to antibodies in general, nor does it give promise of usefulness as a commercial procedure. It is obvious that, if a method for enhancing the efficacy of therapeutic antisera is to contribute to the common good, the method must be made attractive to commercial organizations whose business is the production of antisera. For this reason, the project has become one of twofold importance: namely, the development of the method for concentration and purification of antibodies; and the adaptation of the ultracentrifuge and auxiliary apparatus to routine operation over long periods such as would be necessary when the procedure is carried out on a commercial scale. Positive results in these investigations are potentially of considerable importance in pneumonia serum therapy, for example.

The continuous separation ultracentrifuge, developed by Dr. J. W. Beams, has proved the only device capable of accomplishing the purpose mentioned above. Dr. Beams has cooperated extensively on this project and has encouraged this laboratory to undertake more detailed development of this type of ultracentrifuge in its application to biological fractionations.

The theoretical aspects of this project, necessary to a complete understanding of the mechanisms involved, are more conveniently studied by means of the analytical ultracentrifuge of the du Pont Experimental Station in Wilmington which we have been permitted to use, and the electrophoresis apparatus in our own laboratory; the electrophoresis appara-

tus, described by Tiselius (*Biochem. J.*, **31**: 1464, 1937; *Trans. Faraday Soc.*, **33**: 524, 1937), was mentioned in the last annual report. The apparatus is capable of separating various protein constituents of biological substances by virtue of the electrical charge they carry. For this reason, it is able to supplement the analytical ultracentrifuge by isolating for analysis a component whose ultracentrifuge diagram might normally be masked by additional components. The analytical ultracentrifuge in turn complements the con-

FIG. 1.



Arrangement of units in centrifuge room proper; air compressors appear at left with the two ultracentrifuges along the wall on the right.

tinuous separation ultracentrifuge by defining the optimal running conditions for a desired fractionation. The quantity ultracentrifuge falls in place as a test machine to run preparative procedures on samples too small to be handled conveniently in the continuous separation ultracentrifuge.

A few figures are included to indicate the extensiveness of this project. Fig. 1 is a view of the ultracentrifuge room proper. The two heavy wood boxes appearing in the photograph are barricades to confine damage to the centrifuge in

event of an explosion of the rotating system. The lower box in the rear contains the quantity ultracentrifuge which is capable of handling 100 cc. of material in one run. Swinging an 8 inch duralumin rotor, this ultracentrifuge is run routinely between 500 and 600 revolutions per second, thus exerting a centrigugal force on test material of 60,000 to 100,000 times gravity.

The elevated box on the right surrounded by the platform contains the tubular ultracentrifuge through which it is possible to pass material continuously and thus to handle a much larger volume per hour than is possible with the quantity ultracentrifuge. The rotor of this centrifuge is considerably smaller in diameter than the one mentioned above, consequently more intense centrifugal fields can be obtained through greater rotational speeds. A round figure for centrifugal fields exerted in this system is 250,000 times gravity. Air compressors supplying the ultracentrifuges may be seen at the extreme left of the figure.[1]

Figure 2 is a view of the control room from which both ultracentrifuges are operated. The air controls to both ultracentrifuges are practically identical, the hook-up being copied from the published work of Bauer and Pickels (*J. Exp. Med.*, **65**: 565, 1937). The control panel in the rear is coupled with the quantity ultracentrifuge. That on the left, of which Fig. 3 gives a better view, is coupled with the continuous separation ultracentrifuge. The right side of the control room is a test panel for electrical devices designed for speed measurement, speed control and temperature measurement. Auxiliary apparatus of this type becomes extremely important when an ultracentrifuge is to be operated continuously for periods of 24 hours or more.

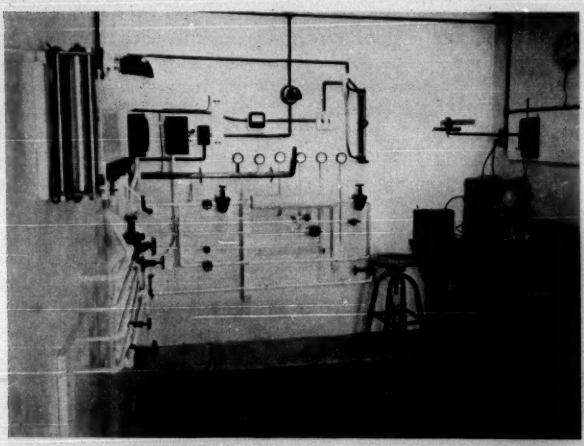
Of the two small panels to the extreme left of Fig. 3 the upper one is for control of oil supply; the lower panel is for control of intake and output of fluid being centrifuged.[2]

[1] Both ultracentrifuges were made in the Rouss Physical Laboratory of the University of Virginia under the direction of Dr. J. W. Beams. The quantity type of ultracentrifuge is described in detail by Bauer and Pickels (*J. Exp. Med.*, **64**: 503, 1936) and Beams, Linke, and Sommer (*R. S. I.*, **9**: 248, 1938). The continuous separation ultracentrifuge is described by Beams (*Science*, **86**: 293, 1937; *Physical Rev.*, **53**: 850, 1938).

[2] The controls for intake and output of fluid had not been installed at the time the picture was taken.

This project which is occupying the attention of the physical-chemistry department has led to the opening up of other problems of theoretic significance. One of these problems has yielded a pneumococcus polysaccharide differing physically from any heretofore described in the literature in that it is substantially monodisperse in intense centrifugal fields. If continued investigation confirms these observations

FIG. 2.



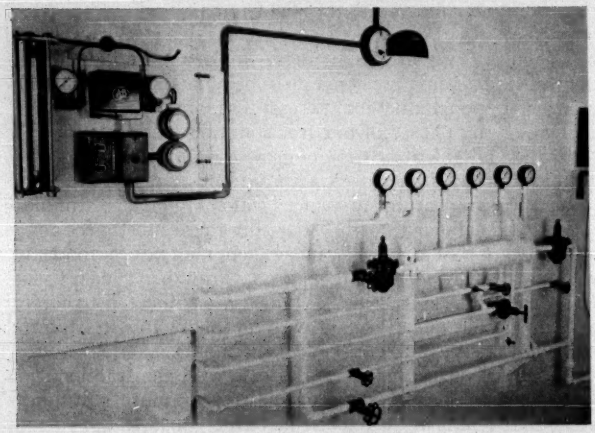
General view of ultracentrifuge control room; control panel on rear wall governs operation of quantity ultracentrifuge while panel on left wall controls continuous separation ultracentrifuge.

it will offer considerable opportunity for a revaluation of immunological studies on pneumococcus polysaccharide.

The physical chemistry department is also carrying on investigations in coöperation with other departments of the laboratory. It is concerned with the orientation nature of the data gleaned, since its place in the organization is that of an engineering department working primarily in applied biochemistry and biophysics. Among coöperative investigations under way at the present time is one concerned with the variability of a pyogenic or pus-producing virus which is

pathogenic for rats and mice. Another problem concerns the fractionation of human and animal allergic sera by means of the electrophoretic apparatus mentioned in earlier paragraphs. The electrophoretic apparatus is also being used in attempts to fractionate nucleoprotein obtained from transplantable rat rumors with the hope of demonstrating fundamental differences between the nucleoprotein of mitotic nuclei and that of resting nuclei. It has also been possible by electrophoresis

FIG. 3.



Full view of control panel for continuous separation ultracentrifuge.

fractionation to isolate a proteolytic enzyme elaborated by a rough strain of *Cl. histolyticum*, eliminating components of the nutrient medium in which it had previously existed. This principle was colorless in buffer solutions and was apparently monodisperse with respect to electric charge.

CHEMISTRY DEPARTMENT.

The investigations of the Chemistry Department during the past year have in general followed along the lines indicated in the previous report. Considerable emphasis has recently

been placed on (*a*) the fractionation of biologically important compounds from tissues, and (*b*) the use of manometric methods for the *in vitro* testing of substances for physiological effects. This report covers in a general way the results obtained during the course of the year, and the present status of the research.

Tissue Fractionation. Most animal tissues, in particular glandular tissues, are storehouses for a great variety of physiologically active substances. Although great progress has been made in recent years in the separation and identification of these substances, this field remains one of the most important for biochemical endeavor. New methods and new tools (e.g. ultracentrifuge, molecular still, electrophoresis apparatus) are constantly being evolved, which offer increasing opportunity for successful separations.

One of the phases of our fractionation work involves the separation and identification of growth promotors and growth inhibitors from tissues such as brain and parathyroid. Tissues appear to contain substances which are able to stimulate or to retard cellular growth. Possibly these substances act as regulators of tissue growth, and as such, may be of importance in the problem of controlling abnormal growth of cancer tissue. The various tissue fractions obtained are subjected to careful tests for their effects on growth of plant roots, bacteria, embryonic tissue, and experimental animals.

A second phase of this work deals with the fractionation of pancreas. This tissue contains one or more substances which play a part in the deposition of fatty material in various parts of the body. The aim of this investigation is to purify and identify the active principle, and to study its value in conditions such as fatty degeneration of the liver, and in arteriosclerosis. Last year a report was made of the isolation, from liver, of the purine base xanthine. This substance had a marked effect in preventing fatty degeneration in the livers of rats treated with carbon tetrachloride or chloroform. It appears that the pancreatic factor in question is not related to xanthine.

Synthetic Organic Medicinals. During the first year of its existence, the laboratory for organic synthesis carried out investigations along three main lines: (*a*) Sulfur compounds,

chiefly condensation products obtained by treating sodium formaldehyde sulfoxylate with primary and secondary amines; (*b*) Arsenic compounds, such as arsonic acid and arsinoxide derivatives of various ring structures; and (*c*) Selenium compounds related to the above-mentioned sulfur compounds. Numerous representations of these three classes have been obtained in pure state. Extensive tests on their physiological effects, bactericidal action, cancer-growth inhibiting properties, etc. are in progress.

Recently the sulfur work has been extended into the important field of sulfanilamide derivatives. Particular attention is being given to the preparation of pyridine, quinoline, and acridone analogs of sulfanilamide. Compounds related to these have been reported to be effective not only against streptococcic infection, but also in the treatment of pneumonia.

Pharmacological Testing by the Manometric Method. Manometric methods offer a simple, rapid method for determining the effects of various substances on cellular processes. An effort has been made to apply this technique to the *in vitro* pharmacological testing of pure compounds or of substances isolated from biological materials, as a preliminary to animal experimentation. Because of the simplicity of the method, a large number of substances can be examined in a short time, the more promising being then selected for further study.

In the early work, thin slices of living animal tissue (brain, kidney) were used as test objects in the manometers. It was found that irregular results were obtained due to variability in the metabolism of the tissue slices from animal to animal. More recently, use has been made of uniform suspensions of various bacteria. These can be obtained quite constant from day to day, and the effects of added substances on their metabolism accurately measured. Tests are now being made by this method on germicidal power, and growth promoting properties.

Linderstrøm-Lang Micro Enzyme Technique. An extensive study is in progress on the enzymatic changes occurring in blood during cancer and other diseases. Rats are used as experimental animals, a drop of blood being removed for analysis every few days during the course of the disease.

The extreme sensitivity of the Linderstrøm-Lang technique permits numerous enzyme analyses to be carried out on a single drop of blood. It has been found that, during the growth of cancer, the proteolytic enzymes of the blood decrease progressively to quite low levels. If the cancer is removed by operation, normal levels are re-established within a few days. An exactly similar series of events occurs during pregnancy. The significance of these observations is now being studied. Work is also being done on the blood phosphatases, the enzymes concerned with the synthesis and breakdown of various important phosphorus compounds in the body. These enzymes have been shown to have a close relationship to cancerous growth, and also to bone diseases such as rickets. Improved methods make it possible to measure phosphatase activity of quantities of serum as low as one cubic millimeter.

Bacterial Enzymes. An interesting example of bacterial adaptability has been uncovered. The proteolytic microorganism *Cl. histolyticum* secretes a powerful proteolytic enzyme which is able to hydrolyze casein, gelatin, and other protein. When the organism is repeatedly subcultured on pure casein medium, it finally produces an enzyme which acts only on casein, but not on gelatin. A gelatin-specific enzyme can likewise be obtained by subculturing the organism repeatedly on gelatin. This ability of bacteria to produce specific enzymes under proper conditions may prove to be of practical value in carrying out difficult protein separations.

Oxidative Metabolism of Normal and Tumor Tissue. Cancer tissue is unable to oxidize carbohydrate in a normal manner. For several years extensive studies have been in progress on the nature of this oxidative defect, and its relation to malignant growth. Use has been made of the manometric technique, in which the metabolic activity of thin slices of living tissue can be determined. For purposes of comparison with cancer tissue, a series of normal tissues has also been studied in this manner. During the past year, embryonic and retinal tissues were added to this series. The first of these is an example of a rapidly growing tissue, and the second resembles cancer in that it is able to form lactic acid from glucose even in the presence of oxygen. These studies

have shown that well-defined metabolic differences exist between cancer and certain normal tissues. However, the complexity of these intracellular processes is such that it is impossible at this stage to draw definite conclusions. Once the oxidative mechanisms are understood, it will be possible to attack the problems of the defective oxidation in cancer.

Another phase of this work deals with the relation of various salts to these oxidative (respiratory) processes. The important observation was made that monovalent anions, such as chloride, bromide, nitrate, or acetate, are essential for the proper functioning of the oxidative mechanism. The significance of this finding is not yet clear, although it appears likely that some of the intermediate enzymes involved are activated by these anions.

Glutathione. Studies have been continued on the problem of the biological role of glutathione, a naturally occurring sulfur (sulfhydryl) compound composed of the amino acids glycine, cysteine, and glutamic acid. Little is known of its function beyond the fact that it acts as a regulator of certain enzymatic processes within the cell. Attention is being given to the question of the source of intra-cellular glutathione. It does not appear to be synthesized directly from the constituent amino acids. Indications are that the proper amino acids are first built up in the correct order as units of protein molecules. Hydrolysis of the latter results in liberation of the glutathione as needed.

In coöperation with the Physics Department *radio-active glutathione* has been obtained by growing yeast in a synthetic medium in which radio-active sulfate is the only source of sulfur. Under these conditions, the growing yeast utilizes the sulfate sulfur to build up glutathione, which can easily be isolated. Radio-active glutathione will be of great value in studies on the fate of this substance in the human body, as there is no knowledge of the mechanism of the action of this important body substance. With radio-active glutathione it will be possible to trace its course and possibly to explain the mechanism of the action. If this is done, it will be one more step towards explaining the riddle of life.

The method of producing radio-active glutathione can be applied to other complex biological substances which have

not yet been synthesized chemically. It opens up an entirely new field whereby body substances can be studied by tagging them with a radio-active atom whose course, combinations and exchanges can be recorded by means of Geiger counters. It is an interesting phase of group work among the chemist, physicist and biologist.

During the past year, a number of improvements were made in methods for measuring glutathione. A simple chemical method for the specific estimation of reduced glutathione was evolved. Like the more complicated manometric method previously used, it depends on the specific activating effect of reduced glutathione on the enzyme glyoxalase. A method was devised for the quantitative reduction of oxidized glutathione to the reduced form, by electrolysis. The usual technique for effecting this reduction (zinc plus acid) frequently gives quite low values in the presence of blood or tissue extracts, so that determinations of oxidized glutathione are low. Finally, improvements have been introduced in the method for isolating glutathione from yeast. By using acetone for liberation of the glutathione from the yeast, the time required for the preparation is very considerably cut down.

Antiglyoxalase. Antiglyoxalase is an enzyme system, discovered in our Laboratory, which is able to bring about the hydrolysis of glutathione into its constituent amino acids. Its importance lies in the possibility that it may act as a regulator of the glutathione supply in the body. This enzyme system is rather unique in distribution, occurring in appreciable amounts only in kidney and pancreas. Work of the past year indicates that the antiglyoxalase complex consists of two distinct enzymes, acting optimally at widely different pH values. They were shown to differ from all other known proteolytic enzymes.

These studies on kidney antiglyoxalase have led into an interesting application in cancer. Reports have recently appeared that a glutathione-hydrolyzing enzyme (presumably identical with antiglyoxalase) is present in blood of cancer patients, but absent in blood of normal subjects. A study is being made of this observation. If it proves correct, it may form the basis of a diagnostic test for cancer.

MICROCHEMICAL DEPARTMENT.

The number of analyses performed was substantially larger than in the previous report period, which is not surprising if one considers the increased activities of the Synthetic Organic Group. But the work of the microchemical department cannot be measured by the number of analyses performed, since considerable research is involved in nearly every sample submitted for analysis. Studies on the reliability of existing methods of analysis, investigations into new methods of detection, development of new procedures, and consulting work in coöperation with the other departments are among the necessary undertakings.

In order to indicate the wide variety of problems handled, some examples are taken at random from the numerous reports given. Some of the problems could be solved only through very close contact with the research workers of the other departments.

Determinations of nearly all of the more common elements were made in the course of the analytical work, either by themselves, in organic and inorganic linkage, or in the presence of other elements. In most instances known macro- or microprocedures could be applied; sometimes, however, to exclude the interference of foreign material, new modifications of approach were necessary. A list of these elements is presented here in alphabetical order; elements more frequently analyzed are designated **, elements handled more than once are marked *. Ag*, Al, As**, Au**, Ba*, Bi, Br, C**, Ca**, Cd, Cl**, Co, Cr, Cu**, F, Fe*, Ge, H**, Hg**, I**, K**, Mg*, Mn, N**, Na**, P**, Pb*, Pd, S**, Sb, Sc, Se**, Si*, Sn.

The problem of qualitative organic microanalysis has been continued, since it can be used with such good effect in routine work. The purity of a compound or its identity with the substance expected can be established in a short time. Some improvements have been inserted into the scheme, as may be seen in a recent note in the JOURNAL OF THE FRANKLIN INSTITUTE. Special emphasis is placed on the semi-quantitative estimation of elements in organic linkages, the interference from other elements, and on microextraction.

The latter process is used in a recent undertaking to determine the total and free cholesterol, blood sugar, phospho-

lipid fraction, and the calcium-potassium ratio in blood samples. These determinations are now carried out on the macro scale in order to find their limitations when applying them to studies on disease; this work is in progress in coöperation with Dr. Joseph B. Wolffe. For smaller samples, refinements such as are necessary in animal experimentation will be developed. A step towards this goal has been made by using Linderstrøm-Lang's finest microtechnique for cholesterol estimations within a range of a few thousandths of a milligram.

As a good example of coöperation between the various departments, the analytical work on samples bombarded in the cyclotron of the Physics Department and the use of radioactive substances in chemical and biochemical work are mentioned here.

Artificially induced radio-active elements play a very important role in recent research work. They may be used for strictly chemical problems, e.g., the testing of the efficiency of chemical separations. Small amounts of a radio-active isotope added to the inactive element will not change the chemical reactions, but any loss of the element in the procedures of filtration, transformation, or separation may be indicated by simply measuring the radio-activity of the otherwise discarded solutions and precipitates. The radiation emitted by these fractions is measured by means of the Geiger counter or by an electroscope, which determines the ionization produced by the radiation. Some examples of this type of work are given later.

The use of radio-active elements is considered especially important in biological and medical research, because the "labelled" or "tagged" elements cannot be differentiated chemically from the inactive elements. By the use of mixtures of active and inactive elements their way through the human or animal body can be traced by the measurement of their emitted radiation. If a known amount of the activated element is used, its distribution and deposition in the body, excretion, etc. can be studied. Complicated exchanges in the body fluids or the metabolism of certain "labelled" compounds are followed by these physical measurements, and thus a new field of biological research has been opened.

Since this type of research is just being begun, only a few results of chemical investigations with radio-active elements are reported. For instance in the removal of traces of other radio-active elements from the main product of the radiated preparation by means of strictly chemical separations, the final products are measured with the Geiger counter without interference from the traces of the transformed radio-active by-elements. Time-consuming double precipitations are necessary for efficient chemical separations in trace analysis, but fortunately their efficiency can be controlled by means of the Geiger counter.

The separation of traces of scandium formed after radio-activation of calcium was accomplished by coprecipitating the scandium hydroxide on aluminium hydroxide; the separation of the calcium from the potassium formed in the same treatment offered no difficulties if a double precipitation of the calcium oxalate was applied.

Another involved radio-active method was the chemical separation of a bombarded silver sample which was contaminated with lead solder, the problem being the separation of traces of radio-active palladium and cadmium from lead, tin, copper, and the main material, the radioactive silver.

In this group of radio-active determinations belongs also the separation of traces of radio-active arsenic from radio-activated germanium, the procedure being rather complicated due to the high volatility of germanium in the presence of chloride and the difficulty in bringing germanium into solution.

In all these cases it was necessary to add known amounts of the inactive trace constituent, i.e., palladium, cadmium, scandium, potassium, arsenic, and to collect the radio-active trace in a bulk of inactive precipitate, double precipitations being necessary to increase the efficiency of the separation in nearly all cases.

The transformation of radio-active sulfur ("labelled sulfur") into magnesium sulfate was carried out by catalytic oxidation of the sulfur to sulfur trioxide in a current of oxygen by means of an improved combustion tube, which was developed in connection with a previous effort to reduce the time for the sulfur determination in organic compounds ac-

cording to Pregl. The sulfur trioxide was absorbed in magnesium oxide, the excess of which was filtered off, resulting in a pure radio-active magnesium sulfate solution of known strength.

Another problem concerns the difficulties encountered with standard procedures of quantitative organic elementary microanalysis whenever rather rarely occurring elements, such as mercury, selenium, arsenic, appeared in the linkage. The selenium determination had to be checked very carefully until reasonable results could be obtained. (This may be due to the very rare use of this method in general laboratories.) Various other procedures have been tested, but the catalytic combustion over a platinum catalyst to selenic acid and the reduction of this to elementary selenium has proved to be the most accurate. Similar observations with regard to mercury determinations have been made concurrently in Germany, and a method developed there is similar to the one which has been used independently in this department.

A generally accepted procedure of analyzing copper-glutathione consists of igniting the sample in a stream of oxygen and weighing the residue, assuming the latter to be pure copper oxide. The results obtained in this way corresponded to those reported by other investigators, but were not satisfactory with regard to the expected purity of the product. By dissolving the residue obtained by the above method in dilute sulfuric acid and depositing the copper in a microelectrolytic cell, 2 per cent lower values for copper were found, indicating the presence of an impurity. Qualitative tests showed silicic acid and sulfate; the silicic acid entered the original sample during a step in the preparation where the solution had to be filtered through Fuller's earth. Whether a mechanical failure of the filter or a soluble double salt was the cause of the admixture has not been investigated further. But the importance of checking apparently reliable results by independent methods of analysis has been clearly demonstrated.

Similar cases, where the results had to be controlled with other methods, were: the selenium determination in the presence of arsenic and halides; mercury determinations in the presence of halides and sulfur; arsenic determinations in the

presence of halides and selenium; nitrogen determinations in the presence of arsenic, mercury and selenium; nitrogen determinations by the Dumas and Kjeldahal methods with regard to linkage of the nitrogen in the molecule.

CYTOLOGY DEPARTMENT.

Radio-active Elements. Radio-active gold and radio-active phosphorus have been used experimentally in the treatment of transplantable rat tumors. However, not all of the possibilities have been exhausted, and work is being continued as there are many more substances to be tested.

The distribution of radio-active gold and radio-active phosphorus after administration to rats is being studied. Data of considerable interest in regard to the location of these elements in the body and their elimination is being accumulated.

Study of Bactericides by Manometric Methods. A correlation of the respiration of *B. coli* in the presence of bactericides with the results of subsequent culture is believed to offer a good method for the study of bactericides in vitro. It has been found that if the respiration of these organisms be eliminated by bactericides the culture is dead so far as subsequent culture is concerned. However, if a trace of respiration is present, later cultures are positive. It is possible to plot graphically the degree of effect of a non-killing concentration of a bactericide by the method. There are probably limitations to the method, of course, but so far as *B. coli* is concerned it works very well.

Injury Hormone. That injury to yeast cells either by heat or by ultraviolet light causes the release of substances which promote the growth of yeast has been demonstrated, both by manometric methods and by cell volume measurements. However, whether the substances may be considered as hormones, as reported in the literature, or simply as food we do not know.

Pharmaceutical Testing.

39 Compounds have been tested for toxicity to animals.

21 Compounds have been tested for therapeutic effect on streptococcus infection.

10 Compounds have been tested for therapeutic effect on trypanosomiasis.

3 Compounds have been tested for therapeutic effect on pneumococcus infection.

3 Compounds have been tested for soporific effect.

2 Compounds have been tested for effect on tumors in rats.

8 Compounds have been tested for germicidal activity.

None of these compounds has shown effects which would indicate any particular value for the treatment of disease.

Allergy. The study of allergic reactions has continued. By the use of the air driven ultracentrifuge and the electrophoresis apparatus it is proposed to separate the anti-bodies from human sensitive serum and determine the manner in which they combine with the substances causing hay fever.

Since these are apparently substances of relatively small molecular size, a series of haptenes has been prepared by coupling arsanilic acid to various protein derivatives in order to study the reaction of antibodies with molecules smaller than proteins. For this latter study serums were prepared by immunizing animals. The experiments are still in progress.

Virus Work. There has been described recently a pyogenic filterable agent which is considered to be a virus. This agent when injected subcutaneously into rats produces pyogenic lesions.

Because the rat may be used as the experimental animal it was considered that this agent was a satisfactory one for use here. Hence some of the material was obtained and preliminary passage in our rats has been made. A series of chemical studies of the agent has been planned as our initial work in the field of viruses.

Cell Nuclear Studies. The work done during the past year has been described in two papers to be published in the January issue of the *Journal of Biological Chemistry.*

The findings may be briefly stated in summarized form. Nucleoproteins have been isolated from three types of tissue, Rat thymus, Walker No. 256 tumor and Philadelphia No. 1 tumor. Four preparations from each tissue showed constant nucleic acid to protein ratio and constant values for the cataphoretic isoelectric point. This leads to the belief that the extracted nucleoproteins represent a preformed combination as present in the cell nucleus. This conclusion is further borne out by the findings on the combination of dyes with the

extracted substances and the tissue nuclei. It was possible to show that the dyeing of extracted nucleoproteins with toluidine blue was independent of the electric charge influencing cataphoretic migration but was dependent upon the charge of the nucleic acid. The amount of dye combined with extracted nucleoprotein or tissue nucleus was quantitatively determined by the amount of nucleic acid in this nucleoprotein or nucleus. At a particular pH the three tissues studied showed amounts of combined dye in exact proportion to their nucleic acid content.

The importance of this finding lies in its application to the study of different nuclei in tissues. By the dyeing technique used to show these quantitative aspects of nuclear dye combination, it was possible to demonstrate clearly that the mitotic nucleus of tumor tissue contained a greater percentage of nucleic acid than the resting nucleus. During cell division more nucleic acid must go into the nucleus. By means of the differential pH dye series, it was also possible to differentiate between the nuclei of different tissues by means of their nucleic acid content. One interesting fact was shown by kidney tissue when this was stained in the pH dye series. In the region of the kidney glomerulus, the dyeing of the nuclei of the proximal and distal convoluted tubules was greatly repressed in alcohol fixed tissue but was normal in mercuric chloride fixed tissue. This is considered to be due to the presence of water soluble basic substances formed in these tubules near the glomeruli, which are washed out from the mercuric chloride fixed tissue but not from the alcohol fixed material.

As a continuation of the above research the fractionation of the tumor nucleoproteins is being attempted in the electrophoresis apparatus. It appears possible to separate a faster moving fraction, which it is hoped will be representative of the nucleoprotein of the mitotic nucleus.

A technique is being worked out by which it will be possible to measure accurately the amount of dye combined with mitotic nuclei as compared with resting nuclei, thus giving a quantitative measure of the relative increase of nucleic acid in the mitotic nucleus.

Studies are also being begun on the breakdown of nuclear substances and nuclei by exposure to ultraviolet rays, X-rays, and radiations produced by the cyclotron.

Studies on Capsule Formation of Pathogenic Bacteria. Most pathogenic bacteria are surrounded by a "capsule." Sometimes the dimensions of these capsules are so large that they may be demonstrated microscopically, while in other cases only serological demonstration (surface-antigens) is possible.

It is generally accepted that these capsules act as a coating around the bacteria to protect them against phagocytosis and that encapsulation is one of the main factors contributing to the virulence of bacteria.

A considerable amount of data is available concerning the chemistry of capsular substances, and serologically, also, capsules have been studied quite intensively. All of this knowledge is passive, however, and is concerned with the capsules after they have been formed; no information is available concerning how and under what conditions capsules are formed.

Since there exists such a close relationship between capsule formation and virulence such a study seems extremely important.

The study was begun from three different angles:

(1) Determination of the conditions necessary for capsule production.

(2) Determination of the conditions inhibitory to capsule production.

(3) Enzymatic destruction of capsules after they once are formed.

A new technique for such studies was developed, since previous studies of this nature had never been made. Capsule sizes were expressed in relation to the viscosity which occurs in growing cultures of encapsulated bacteria, the viscosity being in direct proportion to the size of the capsule. This technique was found to be very satisfactory and revealed some very interesting results.

1. Capsules are formed only when carbohydrate is present in the medium. (Bacterial capsules usually are high molecular polysaccharides.)

2. There appear to be proteins which when present in the medium prevent capsule formation.

3. Capsules are formed only under conditions in which growth is retarded or inhibited by some external factor (the insufficient amount of a certain nutrient element; the accumulation of breakdown products).

4. Certain chemicals or biological compounds added to the medium inhibit or completely prevent encapsulation.

There has been and will be further investigation of the prevention of capsule formation in vitro since preventing of capsules may mean depriving the bacteria of their virulence.

When these "in vitro" factors are known the knowledge obtained will be applied directly to the treatment of experimentally infected animals.

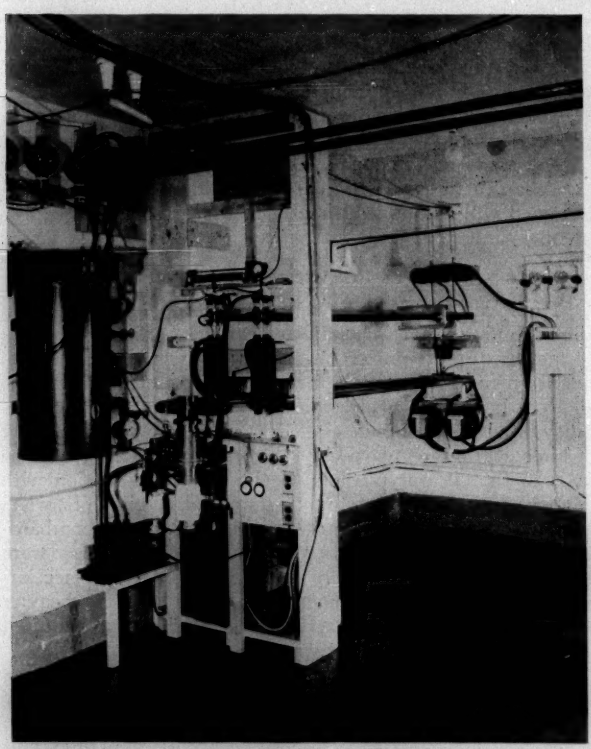
THE CYCLOTRON.

Particles of very high energy were thought necessary in the beginning for artificial disintegration of elements in order to penetrate the nuclei of elements. The application of quantum mechanics to the penetration of potential barriers showed that particles of low energy would have little probability of entering the nuclei of light elements, of which those of biological interest consist. Cockcroft and Walton showed in 1932 that it was possible to observe disintegration with particles having energy of only a few hundred kilovolts, when they observed the disintegration of lithium under bombardment of protons. With potentials up to 600 kv. they were able to disintegrate several of the lighter elements by accelerating the ions from a hydrogen discharge tube. The heavier elements, however, showed no disintegration as these required particles of greater energy.

Since then various methods have been used for accelerating particles such as protons, deuterons or α-particles. The methods may be divided into two classes, the direct method, in which a high voltage is applied to a discharge tube, and the indirect methods. In the indirect methods of accelerating ions, a relatively small voltage is many times applied, as in that used in the cyclotron or magnetic resonance accelerator which has been developed by E. O. Lawrence and his collaborators in the University of California, and reported in 1936.

If a particle of mass m and charge e moves with a velocity of v in a plane at right angles to a magnetic field H, the

FIG. 4.



The powerful short wave oscillator used to accelerate the particles to high energy in the cyclotron, as developed by The Biochemical Research Foundation.

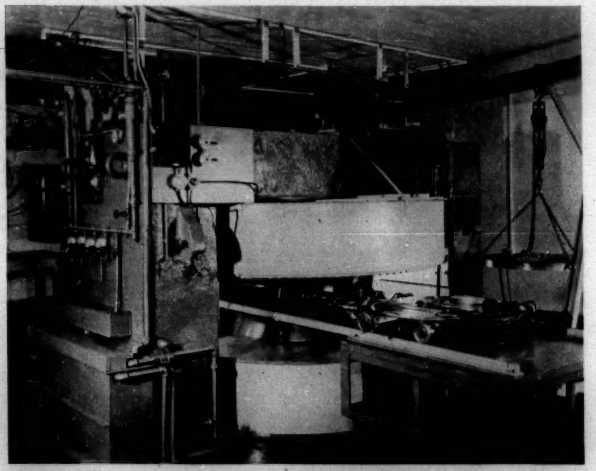
particle will move in circular path of radius ρ where ρ is given by $mv^2/\rho = Hev$.

The ions of the same e/m will have the same time of revo-

lution in the same field and this does not depend upon the radius of the path or on the velocity of the particle.

If an ion starts with a small velocity in a field between two electrodes to which an alternating potential V is applied, when the side electrode happens to be positive, the ion will be driven across and will travel in a semi-circle and return

FIG. 5.



A general view of the cyclotron showing the vacuum chamber removed from between the magnet poles. The cover is removed showing the electrodes (dee's) and the ion source. Since this photograph was taken, the chamber has been modified so as to bring out the beam clear of the chamber.

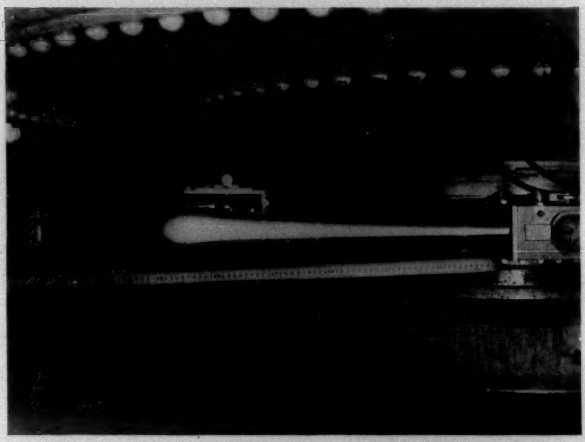
to the gap between the electrodes with the energy eV in electron volts. Then if the other electrode be negative at this moment, the ion will be driven around acquiring another increment of energy eV. It is possible then by adjusting the frequency at the A.C. voltage and the strength of the magnetic field to keep in step with the particle and give it an impulse every time it crosses the electrodes. Our cyclotron is able to give these particles some two hundred 50,000 volt pushes

in 1/200,000 of a second, thus acquiring an energy of approximately ten million volts.

The time of rotation of the particles is proportional to m/e. The frequency of oscillation required to accelerate helium ions under the same conditions is half as great as that for deuterium ions.

At present our cyclotron is delivering a beam of 10.2 million volt deuterons at an intensity of approximately 8

FIG. 6.



A beam of 6 microamperes and 10.2 million volt deuterons emerging from the cyclotron. The range in air is approximately 62 cm.

microamperes. These particles, on emerging from the cyclotron have a velocity of approximately 18,000 miles per second. As these particles emerge and strike the air, a luminescence is produced (Fig. 6) and the range of these particles in air is approximately 62 cm. To date no other man-made apparatus has been able to produce particles of such energy as is now done by our cyclotron.

If, when emerging from the cyclotron, these high energy particles are allowed to impinge on any atom in the periodic

table, the atom is completely disrupted and a new atom formed. Some 500 new atoms have been created, all of which have radio-active properties and are unstable and constantly disintegrating into more stable forms. As they disintegrate, radiations are emitted similar to those emitted by naturally occurring radio-active elements, such as radium.

These radiations may be γ-rays, β-particles, α-particles, positrons or neutrons, or mixtures of all, so that there is a great variation of different kinds, qualities and intensities of radiation produced in elements by the cyclotron. All have a different duration which is spoken of as "half-life" or the time in which one half of the radiations disappear.

The possibilities of the cyclotron are so outstanding that in spite of expense and labor of construction, many machines are now being built in laboratories all over the world although very few are ready for use. There are cyclotrons being built at the University of Chicago, McGill, Princeton, Rochester, Harvard, Liverpool, Cambridge, Moscow, Brussels and other places, some thirty in all.

The physics studies may be directed to the investigation of atomic nuclei, their transmutations when bombarded with different ions, the investigation of the properties of neutrons and the interaction of fast particles with matter.

It is interesting, however, that although investigation in the field of physics was the original idea, the field of physics has gradually diminished in importance by comparison with the enlarging fields of possible study in chemistry and biology. Some physicists in charge of cyclotrons have gone over extensively into the study of the biological effects of these radio-active substances, notably Lawrence and Chadwick.

In chemistry, the use of artificial radio-active substances will fill a place in research even greater than the studies with heavy hydrogen and the natural radio-active elements, which in themselves opened up an entirely new vision; but even this is dwarfed by the possibilities of the use of radio-active substances in chemistry.

Examples of the use of radio-active elements in analytical chemistry and particularly in microchemistry have been already given under the heading of the Microchemical Department.

In chemical research, to determine the final disposition and exchange of atoms in chemical reactions, the radio-active elements open a whole new field of study which is beginning to intrigue the chemists very much. (I confess this was to me rather a surprise as I was absorbed in the biochemical phases of the cyclotron products. I am indebted to Professor Hugh S. Taylor of Princeton for opening my eyes to the possibilities of such chemical study and, while it is rather out of our sphere, we can collaborate with chemists by supplying them with the radio-active material.)

However, while physics and chemistry have interesting applications with the cyclotron, these have a minor place in study to the biological or vital phases. This is true, not only from the humanitarian aspects of the fight against pain and death, but also from the wide scientific field which has opened and is still widening as a result of the application of radio-active material to the study of disease.

The field of study may be considered to have several divisions, but each overlapping the other. The treatment of malignant disease by direct exposure to neutron bombardment has been begun by Lawrence and ourselves and preliminary reports by Lawrence give some encouragement. The quality of radiation differs widely from X-rays in the mechanism of absorption. The X-rays are absorbed by removing an electron from any atom, which in turn produces a comparatively thin pencil of ionization. Neutrons are absorbed by colliding with the atom itself, principally the hydrogen atoms, which in turn produce a very heavy pencil of ionization. This is an entirely different method of radiation and has great promise for study.

Another method is the production of radio-active elements, each element having its peculiar quality of radiation, and the introduction of these into animals with disease. These may either be the pure elements, or the radio-active elements may be put into a more eligible chemical form for use in vital systems. An example of this is radio-active red phosphorus which is obtained by irradiating the element directly, but as this is not a good form to introduce into the body, it is changed to sodium phosphate still radio-active; and a form of therapeutic substance which is well borne by mammalian

systems is thus obtained. To make these chemical changes, elements with a half-life sufficiently long in order to do the chemical manipulation must be chosen. Fortunately, those most important in the study of disease, like phosphorus, sulphur, iron, etc., have a sufficiently long half-life to allow of considerable chemical manipulation.

The action of the body catalysts such as hemoglobin, glutathione, cytochrome, etc., has been a mystery to biologists but the radio-active substances will help to illuminate these secrets of life and in this way lay foundations for a wider study of disease.

These catalysts have not yet been synthesized and are obtained by extraction from biological material. It is possible by chemical exchange to introduce certain radio-active substances into the biological catalyst so the fate of the catalyst may be traced in the body by means of special Geiger counters. In this way certain phases of the mechanism of the action of these catalysts may be traced.

In certain catalysts, the substitution of radio-active "tagged" or "labelled" elements is difficult to introduce. Glutathione is one of these and this catalyst is obtained by extraction from certain yeasts. We have grown a special yeast upon a synthetic medium in which the only sulfur in the medium is radio-active sulfur, produced by the cyclotron. We were able to make the yeast grow and extract from it a radio-active glutathione.

This accomplishment is not only important in itself, but opens the way to the production of numbers of other radio-active body substances which have not yet been synthesized, but extracted from biological material. It is like feeding a hen radio-active calcium to obtain a radio-active egg.

From these statements, it is easy to see that a great new field of endeavor has been opened by the development of the cyclotron and its power to produce radio-active elements for use in biochemical research.

So the future possibilities of biochemical research are increasing enormously. In fact, those who are familiar with it, believe that we are on the threshold of a great era of discovery.

Two Missing Links of Marine Life.—Two missing links of marine life, further supporting Darwin's theory of evolution, have been discovered by eminent British scientists recently assigned to the Bermuda Biological station for a five-year oceanographic survey. One of these discoveries was made by Dr. Robert Gurney of Oxford University who found in the deep waters off Bermuda a minute animal in larval stage which at first seemed to be unknown to science. Later developments in the laboratory at the Bermuda Biological Station at Ferry-Reach however, led to identification of this specimen as a member of the well-known crustacean family classified by scientists as *retrocaris*, a type of river prawn. Similarly, Dr. Walter Garstang also of Oxford University found another tiny sea bottom creature also of the crustacean family, known to science as *Planctosphaera pelagica*. Although a similar specimen had been reported found in 1910, it had hitherto not been classified as a member of the crustacean group. Now, Professor Garstang believes that this small creature is an earlier or larval stage of the better known and more spectacular sea lilies, or some closely related shellfish. The significance of these two new discoveries is that they show the unity of life between surface and sea-bottom marine animals and also definitely establish certain stages of their development from embryo to advanced forms, according to the condition of the environment.

R. H. O.

THE QUANTITATIVE RELATIONSHIP BETWEEN VISIBILITY AND TYPE-SIZE.

BY

MATTHEW LUCKIESH (Director) AND FRANK K. MOSS (Physicist),

Lighting Research Laboratory, General Electric Company, Nela Park, Cleveland, O.

For the reader possessing normal vision the visibility * of printed matter is primarily a function of its size and design, its contrast with the background and the brightness of the background. Among these, the typographer is chiefly interested in the factors of size and configuration or design since these are the factors under his direct control. In general, it is obvious that the visibility of type is increased by increasing its size although the *quantitative* relationship between visibility [1] and type-size is not an obvious one due to the fact that the variable of size follows a law of diminishing returns. This characteristic is usually recognized in designing a series of types of a given type-face. For example, the difference between successive sizes may be as little as ¼ point for the smaller types while the difference may be as much as 4 points or more for the larger types.

An appreciation of the complex response of the visual processes to changes in the character of the object of regard may also be gained from other and related sciences. For example, the illuminating engineer has long known that the quantity of light upon an object must be increased in approximately geometric steps in order to obtain arithmetic changes in visibility. Thus the following levels of illumination (footcandles) are required to produce approximately equal increases in visibility:

1 2 5 10 20 50 100 200 500 1000

It will be noted, for example, that an increase from 500 to 1000 footcandles will produce the same increase in visibility as an increase from 5 to 10 footcandles.

* Throughout this discussion, the term "visibility" is used to designate some degree of supra-threshold visibility.

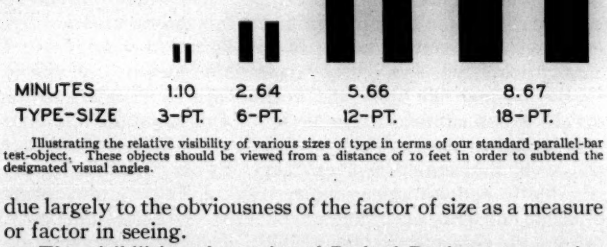
It also may be helpful to consider an example from the science of ophthalmology. In the latter, the ability to recognize an object whose critical details subtend a visual angle of one minute is considered as normal and is designated as 100 per cent. *visual efficiency* according to the scale adopted by the American Medical Association.[2] However, if vision is so impaired that the patient is barely able to recognize an object whose details subtend an angle of two minutes at the eye, his visual efficiency is considered to be 84 per cent., and not 50 per cent. as would be expected upon the basis of the size of object just visible. Thus the ophthalmologist recognizes the fact that size, as a visual factor, follows a course of diminishing returns. It is obvious from these considerations that an understanding of the technique for determining visibility is required in order to appreciate the significance of socalled visibility measurements. Therefore, our methods for measuring visibility are briefly reviewed.

It is the purpose of the present paper to present certain quantitative relationships between type-size and visibility as determined by precise laboratory measurements. Since the *exact* character of these relationships also depends upon such factors as type-face, paper, ink, illumination and others, it is obviously necessary to adopt certain specific conditions for measurement in order to keep the experimental procedures within practical limits. However, the data which are presented are considered to be representative for most modern types and usual standards of good printing. In brief, our experimental conditions involved Bodoni Book type well printed upon a good grade of white non-glossy paper with black ink. All measurements were made under an illumination of 10 footcandles[3] by subjects possessing normal or nearly normal vision.

The simplest scale of visibility now in use is that of Relative Visibility which has been derived for the Luckiesh-Moss Visibility Meter.[1] This scale is formed by a series of test-objects of similar form (see Fig. 1) but varying in size. Thus the visibility of any object, viewed under any condition by any observer, may be expressed as equivalent to that of one of the series of standard test-objects viewed under certain specified conditions. For example, it will be noted from

Fig. 1 that 3-point Bodoni Book type is equivalent in visibility to a parallel-bar or "standard" test-object whose critical details (the width of the bars or the space between them) subtend a visual angle of 1.10 minutes at the eye of the observer. Similarly, 18-point Bodoni Book type is equivalent in visibility to a standard test-object whose critical details subtend a visual angle of 8.67 minutes. In other words, the scale of Relative Visibility provides a "common denominator" for expressing the visibilities of various dissimilar objects just as the values of dissimilar objects may be expressed in ounces of gold. In general, the usefulness of this scale of visibility is

FIG. 1.



Illustrating the relative visibility of various sizes of type in terms of our standard parallel-bar test-object. These objects should be viewed from a distance of 10 feet in order to subtend the designated visual angles.

due largely to the obviousness of the factor of size as a measure or factor in seeing.

The visibilities of a series of Bodoni Book types varying from 3-point to 24-point, as precisely measured with the L-M Visibility Meter and expressed upon the scale of Relative Visibility, are given in Table I. Four of these values are shown relatively in Fig. 1. In obtaining these data, the subjects adjusted the visibility meter until a printed word just

TABLE I.

Size in Points.	Relative Visibility.	Size in Points.	Relative Visibility.
3	1.10	10	4.65
4	1.60	12	5.66
5	2.11	14	6.67
6	2.64	18	8.67
8	3.64	24	11.68

emerged from invisibility and was recognized. As each measurement involved a different word, or several words, the final values obtained may be considered as a measure of the average visibility of the various characters of the alphabet as actually used in words. Thus the resultant of the many dimensional variables involved in the design of the various characters of the alphabet is expressed in terms of a single dimension of the standard test-object. This dimension is the width of the bars of the standard object. It is obtained as a result of an extremely complex summation of innumerable variables by the visual sensory processes of the human seeing-machine. Such a summation does not seem to be possible through the use of mathematical formulae involving matrix information.

Although the visibility data of Table I do not indicate the actual visual effectiveness of these types, they provide a common basis for a more significant interpretation by reference to other related data. It will be noted from Table I that 3-point type is slightly larger than the smallest visible to the normal eye since the normal eye is able to resolve details which subtend a visual angle of one minute. It may also be shown that 18-point type is barely visible to a person possessing a visual efficiency rating of 25 per cent. Thus it is possible to convert the visibility data of Table I into terms of visual efficiency according to the A. M. A. ophthalmological rating. In other words, the visibilities of these types may be expressed in terms of the degree of subnormal vision required to reduce the visibility of each type to the threshold condition. Obviously, data so obtained possess greater visual significance than the "unweighted" values of equivalent size (Table I) since they include the visual effectiveness of the factor of size in seeing.

The relationship between type-size and the ophthalmological rating of visual efficiency, expressed as the per cent. loss in vision required to produce threshold conditions, is given in Table II. These values were obtained from those of Table I by relating the latter with the corresponding values of visual efficiency of the A. M. A. system of rating. It will be noted, for example, that a 2 per cent. loss in vision will reduce 3-point type to the point of invisibility. Hence, a type of this size

TABLE II.

Size in Points.	Per Cent. Loss in Vision.	Size in Points.	Per Cent. Loss in Vision.
3	2	10	48
4	10	12	56
5	18	14	64
6	25	18	75
8	38	24	85

provides an extremely small margin or "factor of safety" in seeing. Similarly, 12-point type is barely visible when the loss in vision amounts to approximately 56 per cent. The significance of the latter datum may be augmented by stating that a child with such a degree of subnormal vision would be placed in a Sight-Saving class in school.

Thus far it has been shown (1) that the visibility of any object may be stated as equivalent to a standard object of definite size; and (2) that the visibility of the latter may be expressed in terms of the loss in vision which would reduce its visibility to a threshold value. It will now be shown that a scale of visibility, similar in principle to the scale of visual efficiency, may be developed in which the degree of suprathreshold visibility (or visibility) is expressed in terms of a change in the *object* rather than in the *visual mechanism* of the observer. The latter scale has been designated as "Per Cent. Maximal Visibility" and abbreviated as *PMV*. Since a detailed discussion of the development of this scale is available elsewhere,[4] it is described only briefly herein.

The two cardinal points on the *PMV* scale are describable in terms of the physical characteristics of two parallel-bar test-objects assumed as standards of maximal and minimal visibility, respectively. The specifications of these standards follow:

100 Per Cent. Visibility. This standard of maximal visibility is obtained with an indefinitely large * black object upon a white background (100 per cent. in contrast) illuminated to 10

* A parallel-bar test-object whose critical details subtend a visual angle of 20 minutes fulfills this requirement for all practical purposes since the image of such an object occupies nearly the entire area of the fovea. In developing the *PMV* scale, the asymptotic value of contrast (1.3 per cent.), derived from the size-contrast relationship, is used in specifying maximal visibility.

footcandles when viewed by a person possessing socalled normal vision. In ophthalmology, a person who could not recognize this object would be designated as blind. The degree of supra-threshold visibility of this object is such that it would be of threshold visibility with a contrast value of only 1.3 per cent.

Zero or Threshold Visibility. This standard of minimal visibility is obtained with a black object, whose critical details subtend a visual angle of 1 minute, upon a white background illuminated to 10 footcandles. In ophthalmology, the recognition of such an object defines the limit of normal human vision. It also represents unity on the scale of Relative Visibility. Obviously, such an object could not be recognized if its contrast-value is less than 100 per cent.

It will be noted that the standards of maximal and minimal visibility are identical with the objects corresponding to the extremes of the scale of Relative Visibility.

Since it is axiomatic that visibility measurements are possible only under threshold conditions, it follows that the degree of supra-threshold visibility of any standard test-object may be determined as a function of the contrast required to produce threshold visibility. For example, it has been shown that 12-point type is equivalent in visibility to a standard test-object whose critical details subtend a visual angle of 5.66 minutes. Obviously, the latter is an object of supra-threshold visibility. However, it becomes an object of threshold visibility when its contrast is reduced from 100 to 3 per cent. This datum is derived from the threshold relationship between size and contrast [5] for parallel-bar test-objects illuminated to 10 footcandles. Similarly, the threshold contrast may be determined for any one of the series of standard parallel-bar test-objects. For objects of minimal and maximal visibility these values are 100 per cent. and 1.3 per cent., respectively. Between these limits, the *PMV* scale is subdivided into 100 equal logarithmic steps of threshold contrast. Logarithmic rather than arithmetic steps in contrast are used in accordance with the well-known logarithmic relationship between contrast and visibility. In general, the appraisal of visibility upon a basis of threshold contrast is particularly justifiable since the perception of contrast is a primary visual function of generally more importance in seeing than the factor of size.

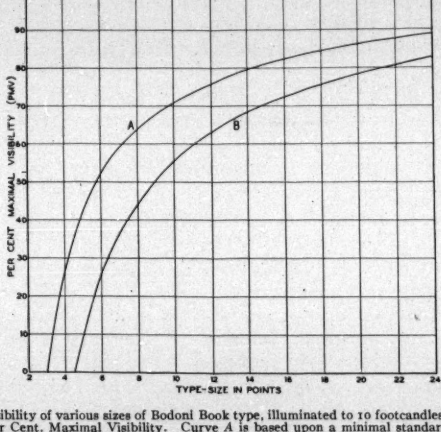
Since each value of Relative Visibility (*RV*) on the scale of the L-M Visibility Meter corresponds to a definite value on the *PMV* scale, it follows that the visibility meter can be calibrated directly in terms of Per Cent. Maximal Visibility. At present, the transfer from the *RV* scale to the *PMV* scale is accomplished by reference to a table of values published elsewhere.[4] In summary, the advantages of the *PMV* scale are: (1) the numerical values of visibility are weighted in accordance with the visual effectiveness of size as a variable in seeing, and (2) all measurements of visibility lie between 0 and 100 rather than between 1 and infinity as is the case with the *RV* scale. The development of this scale was technically possible due to the fact that the same form of test-object (parallel-bar) and lighting conditions were used in calibrating the *RV* scale of the L-M Visibility Meter and in determining the fundamental relationship between the complementary factors of size and contrast. Furthermore, the data obtained in both investigations are highly reliable from the statistical viewpoint. Although this scale has been applied to the appraisal of the factor of size in typography in the present discussion, it is obvious that it is equally applicable for appraising the influence of any controllable factor in seeing.[4]

The relationship between visibility (*PMV* scale) and type-size is shown by Curve *A* of Fig. 2 for Bodoni Book type. In this case, the maximal standard of visibility is arbitrarily designated as that corresponding to 3-point type since the latter is about the smallest which may be read with certainty. Actually, this procedure involves a change in size of the test-object corresponding to minimal visibility from 1.0 minute to 1.10 minutes (see Fig. 1). The advantages of this slight change in the basic value are of a practical nature in that the base chosen is more readily appreciated, in a typographical sense, than some fractional and theoretical type-size.

The relationship between visibility and type-size shown by Curve *A* of Fig. 2 is particularly interesting since the data are weighted in accordance with the actual visual effectiveness of the factor of size. This refinement is essential in comparing the visibilities of various sizes of type upon a true and quantitative basis. In general, it will be noted that the gain in visibility with equal changes in type-size (points) decreases

progressively as the type becomes larger. For example, increasing the type-size from 3-point to 6-point results in an increase of 52 units on the *PMV* scale. Similarly, increases from 6-point to 9-point and from 9-point to 12-point increase visibility 16 units and 8 units, respectively. Thus it is possible to quantitatively appraise the benefit, from the viewpoint of visibility, for any given increase in type-size. The latter datum, considered in relation to economic and other

FIG. 2.



The visibility of various sizes of Bodoni Book type, illuminated to 10 footcandles, expressed in terms of Per Cent. Maximal Visibility. Curve *A* is based upon a minimal standard of visibility corresponding to that of 3-point type. Curve *B* is based upon an empirical standard of visibility, corresponding to that of 4.5-point type, and represents the relationship between visibility and type-size with a minimum of distortion.

factors, should be helpful in determining the *optimum size of type* for a particular use. However, it should be recognized that these values of visibility are obtained only by those possessing normal vision when excellently printed matter is read under 10 footcandles of well-diffused lighting. Obviously, much lower values would be obtained in many practical situations involving subnormal vision, improper lighting, and printing of a poor quality.

A similar relationship between visibility and type-size is

shown by Curve *B* of Fig. 2. This relationship is to be considered merely as a refinement of that shown by Curve *A*. In this case, 4.5-point type rather than 3-point type has been used as a base for the *PMV* scale. This base is calculated from empirical data relating the factors of size and contrast. It corresponds to the threshold characteristics of the smallest object whose visibility is not greatly influenced by inherent optical factors which are of importance only for very small objects. For example, the blurring of the retinal image by the aberrations of the human eye and the distortion of the image due to the finite pattern of the retinal elements (cones) is obviously of much greater importance in the recognition of a very small object than it is for a relatively large object. However, it may be shown that the influence of these factors is of little importance for objects larger than 4.5-point type.[4] Thus Curve *B* of Fig. 2 may be considered as an "undistorted" relationship between visibility and type-size. Obviously, the visibility data of Fig. 2 may also be plotted against any other typographical characteristic such as alphabet length, word count, height of letters, etc.

It will be noted from Curve *B* that visibility increases more gradually, as the size of the type is increased, than is the case for Curve *A*. For example, successive 3-point increases in type-size between 6-point and 12-point result in increases in visibility of 25 units and 13 units, respectively. Obviously, these values are greater than the corresponding ones derived from Curve *A* of Fig. 2 since the "zero" of the scale is based upon 4.5-point type rather than upon 3-point type. Since type smaller than about 6-point is seldom used for prolonged reading, it seems reasonable to assume that the 4.5-point base does not unduly emphasize the relative importance of larger sizes of type. In general, the characteristics of these two scales of *PMV* may be summarized as follows:

Curve A. This scale is based upon the approximate limit in the resolving power of the normal human eye. From a practical viewpoint this limit is obtained with 3-point type.

Curve B. This scale is based upon a size of type sufficiently large to be relatively free from distortions introduced by aberrations inherent to the optical system of the eye and by the finite character of the retinal mosaic. This condition is

practically obtained with 4.5-point type. Hence the values of visibility indicated for larger types by Curve *B* are considered not only quantitatively reliable but also relatively free from distortions.

The usefulness of the relationships of Fig. 2 in typographical practice is due to the exactness and simplicity with which the factor of type-size may be appraised from the viewpoint of visibility. It is perhaps not unreasonable to state that the selection of type-size for text-matter is usually a compromise between definite values of costs and rather ambiguous appraisals of the visual effectiveness of various sizes of type. Obviously, the significance of such a compromise is enhanced when both factors are considered on the basis of accurate and quantitative data. A typographical application of the data of Fig. 2 is cited as an example.

Statistics indicate that the average size of body-type used by newspapers is about 7-point and that some few papers are printed in 9-point type. It is now possible to determine, by reference to Curve *B* of Fig. 2, the actual superiority of the 9-point type on the basis of visibility. It will be noted that the 7-point and 9-point types provide visibilities of 36 units and 50 units, respectively, on the *PMV* scale. In view of the relatively low visibility of the 7-point type, it is obvious from these data that 9-point type is markedly superior to 7-point type. However, from the viewpoint of the publisher, it may be of more interest to compare these types from the basis of a practical or obtainable standard of visibility rather than from that of the theoretical maximal value. For example, it may be assumed that 12-point type represents an "ideal" standard in type-size for newspapers. It will be noted that 12-point type provides a visibility rating of 63 units on the *PMV* scale. Hence it follows that 57 per cent. and 80 per cent. of the assumed standard of visibility is obtained with 7-point and 9-point types, respectively.

Similar comparisons may be made from the bases of other possible standards of visibility by reference to Table III. Obviously, any point on the curves of Fig. 2 may be selected as a standard and the visibility of any size of type expressed as a percentage of this standard of visibility.

In general, research and experience indicate that a type-

TABLE III.

The individual values represent the percentages of various assumed standards of visibility obtained with given sizes of type. The data are derived from Curve *B* of Fig. 2 and are relative values based upon 4.5-point type as a minimal standard of visibility.

Type-Size in Use.	Type-Size Assumed to be Adequate.*				
	8-pt.	9-pt.	10-pt.	11-pt.	12-pt.
6-pt.	57	50	45	42	40
7	82	71	65	60	57
8	100	87	80	74	70
9		100	91	85	80
10			100	93	88
11				100	94
12					100

* By publisher.

size of the order of 12 points is desirable for critical or prolonged reading. However, the size of type which is considered as "adequate" for socalled practical purposes depends upon the relative importance which is attached to such factors as costs and benefits.[6] For example, if an individual publisher considers that 10-point type is adequate or even ideal, this datum forms a definite basis for appraising the percentage of this assumed standard which is actually being obtained by the type which is actually used in practice. If this publisher is using 6-point type he is providing only 45 per cent. of the visibility which he himself considers to be adequate as will be noted from Table III. Thus ambiguity may be eliminated from an important phase of typography.

REFERENCES.

1. M. LUCKIESH AND FRANK K. MOSS. Visibility: Its Measurement and Significance in Seeing. JOUR. FRANK. INST., **220**, 1935, 431.
2. Report of Committee on Compensation for Eye Injuries. Section on Ophthalmology, A. M. A., 1925, 368–377.
3. MATTHEW LUCKIESH AND FRANK K. MOSS. The Visibility of Various Type-Faces. JOUR. FRANK. INST., **223**, 1937, 77.
4. MATTHEW LUCKIESH AND FRANK K. MOSS. Thresholds and Supra-Thresholds of Seeing. *Trans. I. E. S.* (Accepted for publication).
5. P. W. COBB AND FRANK K. MOSS. The Four Variables of the Visual Threshold. JOUR. FRANK. INST., **205**, 1928, 831.
6. The Science of Seeing by LUCKIESH and MOSS, D. Van Nostrand Co. New York, 1937.

Lead for Use in the Chemical Plant.—BRINLEY JONES. *Journal of the Society of Chemical Industry*, Vol. 57, No. 8.) In its function as a resistor of corrosion and because of the simplicity with which it can be fabricated, lead of a high degree of purity is extensively used in construction in the chemical plant; in the rolled, extruded, and cast forms it is variously applied in plant such as sulphuric acid chambers, towers, heating and cooling coils, tank linings, and ammonia saturators. In some of these applications the physical properties of lead may be of secondary interest. Where a long service life is customary and where this is governed by resistance to corrosion alone, there would appear to be little demand for modifications in physical properties. This, however, is not always the case. Failure, at times, is primarily due to mechanical breakdown, cycles of heating and cooling sometimes cause distortion and buckling, and fatigue cracking may result from severe vibration. Mr. Jones has shown that additions to lead of copper, of the order of 0.06 per cent., inhibit grain growth and increase fatigue strength. Tellurium increases the toughness and fatigue strength of rolled and extruded lead. Under conditions of temperature fluctuation, tellurium-lead sheet resists buckling and fracture more than ordinary lead. With reference to lead containing copper and tellurium it is shown that copper in excess of 0.06 per cent. is beneficial in that it prevents the formation of coarse crystalline structures during welding.

R. H. O.

THE FLOW OF COMPRESSIBLE GAS.

BY

B. V. KORVIN-KROUKOVSKY,

Edo Aircraft Corporation.

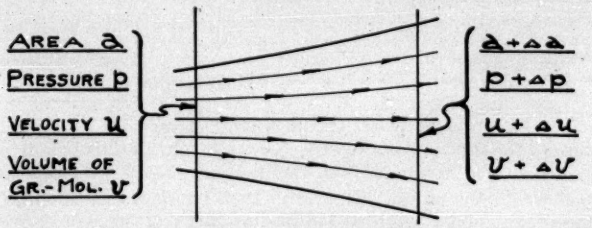
SUMMARY.

The relations are derived between velocity, density and pressure in a flowing compressible gas on the basis of fundamental mechanical principles of the conservation of matter, of momentum and of energy. The results are checked by application to test data on the discharge of superheated steam, and are found to be in excellent agreement throughout the range of pressure ratios from 1.00 to 0.20. It is shown that below certain (critical) pressure ratio the polyatomic gas behaves as monatomic one, indicating that energy transfer ceased between rotational and translational motions of molecules. This phenomenon occurs apparently only in accelerating flow, and the change from acceleration to deceleration liberates the temporarily unavailable energy of rotation, and precipitates the sudden increase of pressure, known as "Compression Shock" in aerodynamics.

In his previous work[1] the author considered the particular case of the flow of compressible gas, that of the efflux from the orifices. The principles of the kinetic theory of gases in regards to the conservation, and to the equipartition of the molecular energy, were used in the derivation of the expressions for the velocity, density and discharge of compressible gas, and these expressions were found to be in good accord with the experimental data. The use was made of the empirical coefficient K, representing the ratio of the momentum of the jet to the product of the orifice area and the differential pressure. The use of this coefficient simplified the solution of this particular problem of the efflux of gas from an orifice, but put the results in the form awkward to extend to the more general cases of the gas flow. Moreover the employment of such an empirical coefficient disguised the effect of the fundamental properties of the compressible gas. In the present work the author develops the laws of the gas flow on basis of these fundamental properties without resorting to the empirical coefficients, and in the form which permits their general application to any range of pressure ratios, either above or below the critical one.

Figure 1 shows a length of a conduit or of a filament of the flowing gas between two transverse sections of the areas a and $a + \Delta a$. At the upstream section the gas pressure, gas velocity and the volume of a gram molecule have the values p, u and v. In transition to the downstream section all of these quantities undergo certain changes Δp, Δu and Δv. For the study of these changes three fundamental relations are available, that of the conservation of matter, of the momentum and of the energy. It is possible therefore to express any three of the above variable quantities in terms of the fourth. In aerodynamics the relation between velocity u and pressure p is of the particular interest. In case of the steady flow the mass of the gas flowing through any one transverse section of

FIG. 1.



A section of a conduit, or of a filament of streaming gas showing, the changes in sectional area, pressure, velocity and volume of the gram molecule.

the stream is the same as that flowing through any other section. Denoting this mass by m, and the mass of a gram molecule by M, the principle of the conservation of matter can be expressed as:

$$m = Mau/v = \text{Const.}$$

The momentum is mu, and the change of the momentum:

$$d(\text{Momentum}) = m\,du = (Mau/v)\,du. \qquad (1)$$

This change of the momentum is produced by the pressure gradient acting along the stream. Considering the volume of gas shown on Fig. 1, the pressure on the right hand side, neglecting the magnitudes of second order:

$$(p + \Delta p)(a + \Delta a) = pa + a\Delta p + p\Delta a.$$

Pressure on the left hand side:

$$-pa.$$

Component of the pressure on sides of the filament taken in the direction of the flow:

$$-(p + \Delta p/2)\Delta a = -p\Delta a$$

$$\text{Net accelerating force} = a\Delta p \tag{2}$$

or for infinitely small increment we can substitute for the accelerating force $a\,dp$. Equating the change of momentum from Eq. (1) to the accelerating force from Eq. (2):

$$(Mau/v)\,du = -a\,dp;$$

cancelling a and transposing, we obtain the differential equation for the change of momentum:

$$-dp = (M/v)u\,du. \tag{3}$$

The equation of energy was derived by the author in his previous work,[1] and can be represented in the form:

$$pv = RT - (M/f)u^2, \tag{4}$$

where f is the total number of degrees of freedom of molecular motion possessing kinetic energy, taken on basis of kinetic theory of gases to consist of three translational, and two or three rotational velocities for diatomic and polyatomic gases respectively. In the differential form the above energy equation becomes:

$$p\,dv + v\,dp = -(2M/f)u\,du. \tag{5}$$

Multiplying Eq. (3) by $2/f$, and Eq. (5) by $1/v$:

$$-(2/f)\,dp = (2M/vf)u\,du, \tag{3a}$$

$$p\,dv/v + dp = -(2M/vf)u\,du. \tag{5a}$$

Adding Eqs. (3a) and (5a):

$$p\,dv/v + (1 - 2/f)\,dp = 0.$$

Transposing:

$$-dv/v = (1 - 2/f)\,dp/p. \tag{6}$$

Integrating between limits we obtain:

$$v_1/v_2 = (p_2/p_1)^{(1-2/f)} = \rho_2/\rho_1, \tag{7}$$

which is the fundamental relation between the specific gravity and pressure in the stream of gas expanding without loss or gain of the total energy, so that decrease of the internal energy is equal to the increase of the kinetic energy of the streaming gas.

DENSITY AND PRESSURE IN ADIABATIC EXPANSION.

It is of interest to derive for comparison the density and pressure relations for the adiabatic expansion of gas under a piston, in which the reduction of the internal energy of the gas E_i is equal to the external work W done on the piston:

$$E_i + W = E_t = \text{Const.} \tag{8}$$

On basis of the kinetic theory of gases we can evaluate:

$$E_i = pvf/2.$$

Referred to one gram molecule of gas the external work W is evidently:

$$W = \int_{v_1}^{v_2} p\,dv.$$

Substituting above values into Eq. (8):

$$pvf/2 + \int_{v_1}^{v_2} p\,dv = \text{Const.}$$

Differentiating:

$$(f/2)p\,dv + (f/2)v\,dp + p\,dv = 0$$

and transposing:

$$-\,dv/v = \frac{f}{f+2}\,\frac{dp}{p}.$$

Integrating between limits:

$$v_1/v_2 = (p_2/p_1)^{f/(f+2)} = \rho_2/\rho_1. \tag{9}$$

Substituting the values of $f=6$ for steam, and $f = 5$ for air we obtain the exponents of 1/1.33 and 1/1.4 familiar to students of thermodynamics.

EXPERIMENTAL VERIFICATION OF THE DENSITY RATIO.

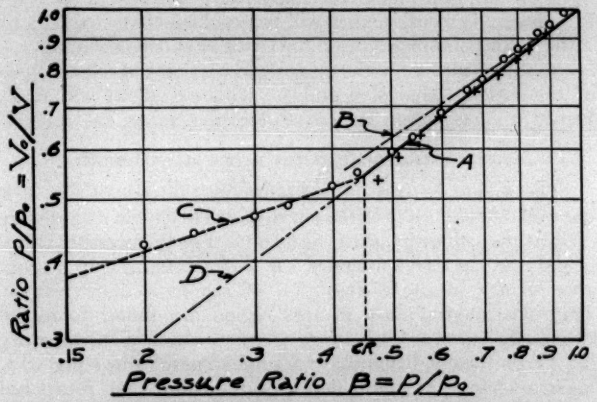
The actual density of the streaming gas can be easily determined by the analysis of the experiments on the discharge

from the orifice in which both the velocity and the weight discharged were measured. The volume of the gas discharged is au, where u is the velocity and a is the jet area, equal to the orifice area in case of the orifice with rounded edges. If w is the weight discharged, the density is evidently:

$$w/au.$$

The original density of the gas at rest can be determined, of course, from the pressure and the temperature of the gas in

FIG. 2.



Density ratio plotted as function of the pressure ratio for superheated steam flowing through the orifice with rounded approach. Circles are from tests of Warren and Keenan,[2] and crosses from Steam Nozzle Research.[3] The change of slope between curves A and C indicates that important change takes place in the distribution of the molecular energies at (critical) pressure ratio of 0.45.

a vessel before expansion. The calculations of the actual density ratio ρ/ρ_0 were made by the author using this method for the discharge of the superheated steam,[2, 3] and the results are plotted against pressure ratio on Fig. 2. For the higher range of pressure ratios the experimental points follow closely the straight line marked A, which has the slope of 1/1.33 corresponding to Eq. (9) with $f = 6$.

The Eq. (7) used with the same value of $f = 6$ gives the curve marked B on Fig. 2, which is not in as good agreement with test results as the curve A representing Eq. (9). The

discrepancy between Eqs. (7) and (9) is not in the method of their derivation, but is contained in the basic energy Eq. (4). Indeed the value of v, and therefore the density ratios, can be computed directly by Eq. (4) substituting in it the experimental values of p and u, and the density ratios computed by this method are found to follow closely the curve B of Fig. 2.

While Eq. (9) is found to be in better agreement with experiment than Eq. (7), the latter has the advantages to be discussed later, and therefore will be retained in the remainder of this work. As a practical expedient for increase of accuracy in numerical calculations it will be assumed that f exceeds by 2 the values commonly used for gases in stationary state, i.e. is equal to 8 and 7 for the steam and air respectively, instead of theoretical value of 6 and 5. This expedient will make Eq. (7) to conform to the curve A of Fig. 2.

DENSITY RATIOS FOR PRESSURE RATIOS BELOW CRITICAL.

The salient feature brought out by the plot of Fig. 2 is the well defined break in the curve of density ratio vs. pressure ratio at the value of 0.45 of the latter. For the pressure ratios below 0.45 the curve assumes a new slope, indicating a probable change in the distribution of the molecular energies. The experimental data in this region are found to follow closely the curve C of the slope of 1 : 3, which is indicated by Eq. (7) on the condition that f assumes a new value equal to 3. Such a change in the value of f indicates that rotational velocities have ceased to take part in the interchange of energy in collisions of molecules, and that only the energy of translational motion remains available. The fact that such a change may occur in a gas is indicated by the application of quantum mechanics to the kinetic theory of gases.[5] It is shown that rotational energies which the molecule can take are restricted to a limited number of discrete values, and that certain minimum energy of translation is required in collision of two molecules in order to produce the change from one rotational energy state to another. If the energy of translation is reduced below this minimum value, the molecular collisions do not produce any further change in the rotational energies, and the gas behaves as monatomic gas with its

appropriate value of $f = 3$. The use of Eq. (7) was retained in this work because it produces the experimentally verified curve C upon substitution of $f = 3$.

It must be observed here that translational energy of the molecules of steam at the pressure ratio of 0.45 in the tests illustrated by Fig. 2 exceeds by some 30 or 40 times the energy of the rotational quanta for water vapor in stationary state. Apparently in the condition of the accelerated flow from the test nozzle there are unknown factors which cause cessation of the energy transfer between translational and rotational motions of molecules at the energy level exceeding by many times the value of rotational quanta for the gas in normal state. The significance of this phenomenon will be further considered at the end of this work.

VELOCITY AND PRESSURE RELATIONS FOR PRESSURE RATIOS ABOVE CRITICAL.

Denoting by:

E_i, internal energy of gas,
E_u, kinetic energy due to streaming velocity u,

we can write for the change from the state 1 to the state 2 of the gas:

$$E_{u2} - E_{u1} = E_{i1} - E_{i2}. \tag{10}$$

The kinetic energy of streaming per gram molecule of mass M is:

$$E_u = Mu^2/2. \tag{11}$$

The internal energy of gas is:

$$E_i = fpv/2; \tag{12}$$

from Eq. (7) it follows that:

$$v_1 p_1^{(1-2/f)} = v_2 p_2^{(1-2/f)} = v_0 p_0^{(1-2/f)}, \tag{13}$$

where v_0 and p_0 denote the volume of the gram molecule and the pressure of the gas at rest. Eq. (13) can be transposed as follows:

$$p_1 v_1 = p_0 v_0 (p_1/p_0)^{2/f} = RT(p_1/p_0)^{2/f}; \tag{14}$$

likewise:

$$p_2 v_2 = RT(p_2/p_0)^{2/f}. \tag{15}$$

Substituting now Eqs. (14) and (15) into Eq. (12), and then Eqs. (11) and (12) into Eq. (10):

$$M(u_2^2 - u_1^2)/2 = fRT[(p_1/p_0)^{2/f} - (p_2/p_0)^{2/f}]$$

or transposing, and substituting $R/M = gB$, where B is the gas constant for the particular gas referred to the unit of weight:

$$u_2^2 - u_1^2 = fgBT[(p_1/p_0)^{2/f} - (p_2/p_0)^{2/f}]; \qquad (16)$$

for the particular case of the discharge from an orifice, where $u_1 = 0$ and $p_1 = p_0$, we have:

$$u^2 = fgBT[1 - (p/p_0)^{2/f}]. \qquad (17)$$

The weight discharged from the orifice with rounded edges is evidently:

$$w = a\rho u, \qquad (18)$$

where a is the area of the orifice,

u the velocity determined from Eq. (17),

ρ the density of discharged gas in gravity units. This can be obtained from Eq. (14) by substituting $v_1 = Mg/\rho$ and $R/M = gB$, yielding:

$$\rho = p/BT(p/p_0)^{2/f}. \qquad (19)$$

This form is convenient for use in connection with Eq. (17), as both include the same function $(p/p_0)^{2/f}$.

PRESSURE RATIOS BELOW CRITICAL.

When the state 2 of the expanding gas involves the pressure ratio below critical, the pressure-density relation is not a continuous function, but is represented by the broken line A and C on Fig. 2. Therefore Eqs. (10), (11) and (12) for the internal energy will take the form:

$$E_{i1} - E_{i2} = f(p_1v_1 - p_cv_c)/2 + 3(p_cv_c - p_2v_2)/2, \quad (20)$$

where p_c and v_c denote the pressure and the volume of the gram molecule of gas at critical pressure. The value of $f = 3$ is substituted for the pressures below critical, as this corresponds to three degrees of molecular freedom in translation, representing the constant universal for all gases. For p_1v_1 we can substitute Eq. (14), and the expression for

$p_c v_c$ takes the same form. For $p_2 v_2$ we can substitute on basis of Eq. (15) with $f = 3$:

$$p_2 v_2 = p_c v_c (p_2/p_c)^{2/3} = RT(p_c/p_0)^{2/f}(p_2/p_c)^{2/3}; \qquad (21)$$

making these substitutions in Eq. (20) we get:

$$E_{i1} - E_{i2} = fRT[(p_1/p_0)^{2/f} - (p_c/p_0)^{2/f}]/2 + 3RT[(p_c/p_0)^{2/f} - (p_c/p_0)^{2/f}(p_2/p_c)^{2/3}]/2.$$

Equating the change of internal energy to the change of kinetic energy, transposing and letting $R/M = gB$, we get the final expression for the change of velocity with the change in pressure:

$$u_2^2 - u_1^2 = fgBT[(p_1/p_0)^{2/f} - (p_c/p_0)^{2/f}] + 3gBT(p_c/p_0)^{2/f}[1 - (p_2/p_c)^{2/3}]; \qquad (22)$$

for the particular case of the discharge from the orifice, substituting $u_2 = u$, $p_1 = p_0$, and $p_2 = p$ we have:

$$u^2 = u_c^2 + 3g\,BT(p_c/p_0)^{2/f}[1 - (p_2/p_c)^{2/3}], \qquad (23)$$

where u_c is the velocity of discharge at critical pressure determined by Eq. (17) substituting u_c for u, and p_c for p.

The weight of the gas discharged can be again computed by Eq. (18), but the density in this case is determined by the use of Eq. (21) and becomes:

$$\rho_c = \frac{1}{BT}\,\frac{p_2}{(p_c/p_0)^{2/f}(p_2/p_c)^{2/3}}. \qquad (24)$$

The subscript c is added in order to distinguish the density as given by Eq. (24) from that of Eq. (19), and in order to emphasize that it refers to the point on the curve C of Fig. 2.

THE CHECK OF FORMULÆ.

The experimental data are not available to check the general Eqs. (16) and (22), but tests on the efflux of gas from an orifice are available for steam and for air, and can be used to check the Eqs. (17) and (23). The tests made with superheated steam [2] are particularly valuable as they included the determination of steam velocity for the pressure ratios as low as 0.20. Figure 3 shows the velocity coefficient defined as the ratio of the experimental to the calculated velocity. The

velocity was calculated by Eqs. (17) and (23) using the value of $f = 8$, as this was explained already when discussing the verification of Eq. (7). The value of B for the superheated steam was taken as 85 in Lbs.-Cu. Ft.-°F. units, the value which was found to check well with Peabody's Steam Tables.[6] The curve of Fig. 3 shows the excellent agreement of test results with the experimental data, particularly con-

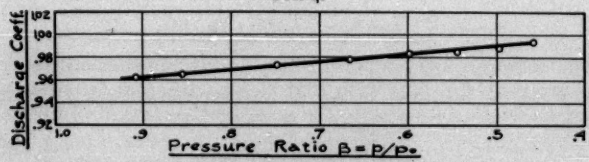
FIG. 3.

Velocity coefficients for the discharge of superheated steam through the orifice with rounded approach for wide range of pressure ratios.

sidering the wide range of the pressure ratios covered. The velocity coefficient gradually grows from 98.2 per cent. at $p/p_0 = 0.95$ to 99.4 per cent. at $p/p_0 = 0.20$.

The experimental data on the discharge of air [4] covered only the pressure ratios above critical, and did not include the measurements of velocity, but only of the weight of the air discharged. The coefficients of discharge plotted on

FIG. 4.



Discharge coefficients for the air flowing through the orifice one inch in diameter with rounded edges.

Fig. 4 were computed from these data by the use of Eqs. (17), (18) and (19) with the value of $B = 53.34$, and $f = 7$. The agreement of the calculations with test results is again satisfactory, and the general trend is again towards increase of the coefficient with the increase of the Reynolds' Number, which is in accord with the experimental investigation of the flow of liquid through standard nozzles.[7]

DIVERGING FLOW.

The application of Eqs. (17) and (23) to the discharge of steam from the orifice with rounded approach provided the experimental verification for the particular case of the converging flow in the direction of the falling pressure gradient. This can be considered as reasonable verification of more general Eqs. (16) and (22) for such a flow. The data are not available for the checking of these expressions for the case of the divergent flow, or the flow with negative acceleration against rising pressure gradient. For the flow above the critical pressure ratio there is no reason to doubt that Eqs. (16) and (17) will apply, as there are no changes in the properties of the gas which affect the distribution of molecular energies.

For the pressure ratios below critical the situation is entirely different. Below this pressure ratio the gas acquired new properties which may modify its further behavior. Were the gas made to expand relatively slowly under a piston, the ratio of specific volumes would have followed the line D of Fig. 2, and the equipartition of energy between translational and rotational motions of molecules would have been preserved. In case of the free expansion in flowing from the orifice the equipartition of energy between translational and rotational motions of molecules apparently ceases at the critical pressure ratio, and for the lower pressure ratios the rotational energy becomes unavailable. This is shown on Fig. 2 by the line C indicating lower pressure p for a given specific volume V than would be given by the line D. At the point of minimum sectional area of the convergent nozzle the gas contains in latent form the internal energy measured by the horizontal distance between the curves C and D for any specific volume V.

It is not known what the mechanism is that causes the cessation of the energy transfer between rotational and translational motions of molecules at critical pressure ratio, and at the energy level corresponding to many times the lowest rotational quanta for the gas in normal state. It appears, however, that it is connected with the case of accelerated flow and falling pressure gradient. The change from acceleration to deceleration apparently restores the equipartition of

molecular energies, thereby liberating the heretofore unavailable energy of rotation, and precipitating the sudden increase of the pressure. Such a sudden increase of the pressure was observed in high speed wind tunnels at or past the point of maximum constriction of the air flow, and became known under the name of "Compression Shock."

REFERENCES.

1. B. V. KORVIN-KROUKOVSKY. Efflux of Gases Through Orifices—Kinetic Theory. JOURNAL OF THE FRANKLIN INSTITUTE, 225, No. 1, January, 1938, pp. 81–93.
2. G. B. WARREN AND J. H. KEENAN. A Machine for Testing Steam Turbine Nozzles by the Reaction Method. The American Society of Mechnical Engineers, 29 West 39th Street, New York, N. Y., Reprint No. 2001 of the paper presented at the Midwest Power Conference, Chicago, Ill., January 26 to 29, 1926, Table I on page 42 and Fig. 15 on page 56.
3. Steam Nozzle Research. *Proceedings Institution of Mechanical Engineers.* Storey's Gate, St. James' Park, London, S.W. 1, May, 1925, Table 27, pages 802 and 803.
4. JOSEPH A. POLSON, JOSEPH G. LOWTHER AND BENJAMIN J. WILSON. The Flow of Air Through Circular Orifices with Rounded Approach. Bulletin No. 207, Engineering Experimental Station, University of Illinois, page 40, Table 14.
5. EARLE H. KENNARD. "Kinetic Theory of Gases," First Edition, Chapter VI, Sec. 147, Quantum Theory of Specific Heat, p. 255, McGraw-Hill Book Co., New York and London.
6. CECIL H. PEABODY, "Tables of the Properties of Steam," Eighth Edition, John Wiley and Sons, New York.
7. H. MUELLER AND H. PETERS. Coefficients of Flow of Standard Nozzles. Technical Memorandums of National Advisory Committee for Aeronautics, No. 549, January, 1930.

LET US START ALL OVER AGAIN.

BY

RAYMOND E. TIFFANY.

With all divisions of scientific research uncovering hitherto unknown details of energy, structure, composition of mass and motivation of mental process, the tremendous amount of laboratory fact that has accumulated is beginning to clog the understanding and appears to be erecting an insurmountable mountain of obscurity about the entire subject of a planned or orderly creative process.

In the march of this achievement of knowledge and the analysis in our laboratories of the construction of matter, why not stop a moment and consider that the plan of the construction of a thought might unlock the answer to the creation of the Hydrogen and Helium atoms, and with it, the mode of procedure to be adopted to create the atomic scale of elements in the laboratory?

The entire scientific world has had for the last thirty years an epoch of unparalleled richness. It has been quite like the farmer in the winter time when he goes down into his cellar and sorts the apples. Neither the farmer in his cellar nor the scientist in his laboratory has found a single good apple or a rotten one or a so-called new idea or thrown out a bad old idea that was not already in the barrel, or in existence, when he began his search for good apples or good principles. The facts were present all the time but neither knew just exactly which would hold up and which should be thrown away.

This sorting over process in the various laboratories however has brought to light so many excellent products that the very thought of them should make us stop—look—and listen. Where are we going? Are we getting into the swamp by knowing too much or are we going to be able to co-relate these facts into a plan of causation? We are stripping nature to the raw but at the same time it may be a boomerang. Is it going to be possible to co-relate this knowledge? Just how can it be done? Where should the process of co-relation start? Is

there a deterministic formula or will it be indeterministic? Is determinism purely a mental qualification applying to a few individuals or does it represent a particular fundamental idea in the types of creative circuits?

Inasmuch as these facts were already in existence and have been for millions of years, it is new, *only* to our particular group mental process. And since this relationship between our mental ability and the attack upon matter process has been so persistent throughout the world it must be about time that we go back to Aristotle and bring out one of the seeds he gave us on thought and matter but which we have persistently kept in the background. His essence was "that all matter has within itself a particle of that thing we call thought" (he did not say that matter could think).

The entire subject, however, must begin with the idea that what is commonly known as truth is a highly variable factor. What I say may not be the truth. What you say may not be the truth. But between what you say and what I say there must be a related position of what might be termed "abstract or absolute truth." This quality of truthfulness is quite like high fidelity in radio receiving and broadcasting. What we must first be interested in, then, is just how far each one of us may distort the facts of laboratory investigations.

In other words, before we even begin to attempt to formulate any plan of co-relation of science, we must have a mental qualification that is flexible, ready to take hold of an idea, able to examine it and qualified to take the good out of it and discard the waste. We must qualify as being a good apple sorter of scientific fact. Apparently, we are in a period of the development of the world when we are throwing overboard many things that we were taught as being absolutely false or at least highly distorted. On the other hand, we have not yet arrived at the proper period when these good things can be properly planted and raised to maturity since we are still looking through the barrel of apples of scientific endeavor.

The type of mind that is doing the searching is extremely vital. No really vital development in world history was ever made by a person who was driven by the fundamental impulse that he had one chance in ten, a thousand, or a million that he could do what he set out to do. He knew he could do it.

There was no chance at all, but there was a great deal of not knowing *when* it would be accomplished. He cared not about the *when* since he knew that it would be done eventually.

All persons, whether they are scientific workers or the ordinary men on the street, are roughly divided into two classes, such as determinists and indeterminists. Of course, we find that we all are what we might say as being a mixture of both. However, if we establish a limit of one hundred as the total of both circuits in each of us, we can see that a 50/50 fellow just does not care which way the thing works or even if it works at all. On the other hand a 96/4 is a perfect full fledged determinist, while 4/96 is a full fledged indeterminist. We are not to be disinterested because he is of opposite sense to us since we first must realize that *he is*; and consequently the proper plan of any co-relation of science must include what he thinks as well as what we think. In other words, the entire proposition must eventually be laid out so that both types of persons who are amenable to Reason will thoroughly agree upon it. Whether the indeterminist believes in a paper plan or not does not matter. When he sees results in absolute concrete form of matter processes he will think there is a great deal to it, even though he never will believe it.

If we accept the major division of man's mental processes as being of a deterministic nature or an indeterministic nature just how can we tie these two opposite senses together into a principle of creation? In order to be able to understand matter, we must first understand man as we must understand this galaxy before we can attempt to tell what those stars are doing outside of our galaxy. We must keep our feet on the ground. We must be able to organize our own individual mental coördination into a few fundamentals of known truth and stick to them.

To begin with, then, must we not realize the fundamental difference between a determinist and an indeterminist and their relative basic mental types? We will not attempt yet to determine why one is of one opinion and the other is of another, but if we can indicate a primary quality of a basic mental conception that is indicated by both types and common to both, we will begin to see why it is absolutely necessary to have both types.

Primarily, the determinist has a type of mind that steadfastly believes that there is a universal principle of operation that governs all life and force on this earth or in this galaxy. The determinist, of course, may have a varying degree of intensity of belief, as it were, and he may have a few things that are not moved according to this universal force or principle; but in the maximum case he believes that all things are moved according to some unknown periodic or cyclical law. In simpler form, when it is all boiled down, the 100 per cent. determinist is the man who has a God large enough to do all things. His God is not the God of the organized church. He is not much interested in their picayune God who can do only a few things part of the time.

On the other hand, we have the indeterminist who lays all to chance and believes that man himself is able to overcome his handicaps. However, when he comes to mental handicaps to hurdle he is lost. He, of course, is not entirely an indeterminist any more than all the determinists are 100 per cent. There are many avenues in which he believes in a fixed progressive plan of causation, but these all arise from a principle of *matter* causation rather than *mental* excitation.

Now, if we consider that mankind is one avenue of the manifestation of the construction of matter, and its body includes the entire atomic table, then it is highly probable that the mental processes of mankind *might possibly* have a parallel condition since mind and matter function together so consistently. If it were possible to indicate two types of being or condition that could be likened electrically to capacity and induction or static and magnetic, each of these types of force would have within itself a particle of the other type, in a ratio of 3 : 1 or 1 : 3 according to electrostatic and electromagnetic law of force and current. Obviously from our radio laws we know that the induction and capacity must balance and are of opposite sign; also that the field of one is many times the size of that of the other.

From the medical laboratories we also have sufficient supporting evidence that there is a possibility of mental behavior being a process closely related to Radio law. So that if we make the jump and say that Man's mind *is* a radio set

we will see two basic types of condition, i.e. $(-\ I\ +\ C)$ or $(+\ I\ -\ C)$ as circuit requirements for resonance.

Now, if we recognize that in the signs above $-$ the negative (electronic) sign is also one of giving or going and the positive is a pole of reception, we can possibly obtain a partial glimpse of what will happen to the two men, if one is basically $(-\ I\ +\ C)$ and the other $(+\ I\ -\ C)$, when both are energized by an identical force. One will give us something while the other will receive something. And this is the essential difference between whether we feel mankind has the say, hence the indeterminist, or whether a universal force drives us along and with us every other thing that was created or destroyed. The Quantum Theory accounts for the unit measure of the whole circuit when energized, together with the intermittent tuning to particular events or things.

In support of this principle of differences, it has been recognized that the identical stimulant has opposite effects upon two classes of people. This definitely shows that the primary energy circuit of the body has two distinct polarities, if we transpose the idea of "a Stimulant" to the idea of added E value to the circuit as represented in the E charge in the nucleus of the atom being used and its effect upon particular body circuits.

In connection with these essential differences between determinism and indeterminism, we see a comparable difference between the lawmaker and the policeman; between the architect and the contractor; between idealism and materialism. All the dictates of the mind as manifested by their relative intensity on either side of the circuit—greater Inductive or greater Capacitive quality of the particular circuit involved.

The intensities of both qualities vary in successive degrees on both sides of the circuit in a fixed sequence of relationship as indicated by the conditions of I feel, I think, I believe and I know.

"I feel" is pure power or intuitive sense without ability to tie it up to anything.

"I think" is the first stage of concentrated direction of the intuitive sense. It is an intermediate quality before understanding.

"I believe" is the balancing of the second stage with a sense of experience of equal value, but not yet thoroughly understandable. It is also an intermediate quality before understanding.

"I know" is the completed thought when it is ripe and suitable for distribution and is understanding.

This sequence is quite like the idea of planting a seed in the spring; the extending of its stalk in the summer; the forming of its seed pods in the fall; and the collection or unification of all the completed units into a ripe and mature fruit or thought which will be profitably consumed by other bodies or persons.

Mental processes therefore must be solved before matter processes. The type of atomic construction that will appear after the architecture of mental processes is established will give the necessary understanding to unlock the atom with an extremely minute force, rather than by the use of the increasingly larger sizes of atom busters. Why not walk into the vault of the atom with the right mental combination, similar to the cashier who walks into his vault with the right MENTAL combination, instead of trying to break the vault open like a robber? First we must be able to perceive and balance the mental relationship.

It seems quite appropriate to me that the first step in any synthesis of laboratory fact should begin with an understanding of these two basic types of minds, since this was essentially the basis of the really first difference of importance between Plato and Aristotle. We must consider that as civilization progresses, each of us, at any age, adds but an extremely minute part to the whole. Also that some of the old ideas were really fundamental facts of truth, although they were not able to confirm their statements as well as we should in this day of precise laboratory equipment. However, there were a few elements that were taught then that are equally true today; and the problem is to identify a few principles as fundamental qualities of electrical circuits that were true and stated then and are also true today as known laboratory fact.

There are too many evidences of constancy coupled with a progressive-variable to establish what would be termed a fixed pattern of any type of life or causation; but there are sufficient repetitive patterns that include a progressed variable

to indicate that the creation of any atom is according to a fixed pattern of being which will vary within certain limits. The same variable repetition also occurs in our mental processes. We never see the same thing in "exactly the same way" the second time we see it.

In this attempt to set up an inductive plan of comprehension, only the determinist will understand. He is the fellow who knows it can be done when every one else tells him he is crazy. It was never done before. They are the true creators. The indeterminist, however, will use this plan to greater advantage to humanity for his is the type mind that puts the use of the plan into physical accomplishment. One is the original creator—the architect; the other is the contractor, both being required and each equally important. But greater coöperation or coördination is needed. The circuit must oscillate between inductive mental processes and capacitive matter processes. The mass mind is indeterministic.

The formation of any belief, then, is the first step of the plan; for unless we understand what excites our mind into any type of belief, how can we ever begin to understand the use of that particular circuit in the creation of matter? To our mind, it makes no difference in processes whether you believe in "God the Father, the Son and the Holy Ghost" or whether you believe you will buy a new suit; you will go to a prayer meeting; you will get drunk. All of these are first excited into perception and action—Mental or Physical. What causes this prime excitation anyway? If we liken the basic qualities of man to two basic types of circuits that are inherent in each, it is evident that these circuits must be excited to create any interest whatever. The first step then is INTEREST which might also be defined as crystallized or completely formed intuition or electrically it is just plain Energy—or Electromotive force.

We must start over again at the beginning. We must go back to kindergarten again and build upon a new foundation of fact. We must choose a datum point or bench mark of "beginning" from which we can start from and check to. We are naturally limited in our choice of this point since there is only one fixed center or base point in our entire galactic system. One point about which all life revolves. One point which

gives a common ground for all circuits—the Sun—the "A" Battery of Causation.

With present day laboratories we should be able to confirm our findings very readily; but before we begin again, let us return to a keener analysis of human behavior and find that thing in our mind that Aristotle told us was also in matter. Find that thing that first excites any belief in anything, and then differentiate it with "I feel," "I think," "I believe," and integrate it with "I know."

Once this is recognized, we arrive at the point where we can put our mental processes on the same exact plane of analysis with any radio circuit and determine the amount of distortion and true fidelity in our own thinking processes. For some place between what I think and what you think, there must be a position that can be recognized as true fidelity or absolute truth.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

LAWS OF TURBULENT FLOW IN OPEN CHANNELS.

The first attempts of hydraulic engineers to formulate the laws of flow in open channels, such as canals and rivers, date back to the latter part of the eighteenth century. At this time Chezy proposed his famous formula for determining the velocity of flowing water in terms of the dimensions of the channel and the slope of the water surface. This formula contained a quantity, the so-called Chezy coefficient, the value of which was to be determined by experiments. Chezy believed his coefficient was a constant having a value independent of the size of channels or of the nature of their surfaces. It took nearly half a century to discover that this belief was wrong.

In 1857, Darcy and Bazin commenced a comprehensive series of well-planned tests in order to place the laws of flow in open channels on a firm foundation. As a result of the tests, Bazin was able to show that the Chezy coefficient was a quantity the magnitude of which depended not only on the size of a channel but also on the nature of the channel bottom and side surfaces. Practically all of the formulas used by hydraulic engineers today, both here and abroad, can be traced back to Bazin's work.

These formulas, which are in common use, are defective in form from the strict scientific viewpoint. As a result there is always some uncertainty in their application. For example, when model experiments involving flow in open channels are conducted, the transfer of the results from the model test to the actual structure is either very difficult or is of doubtful value.

A paper by G. H. Keulegan in the *Journal of Research* for December (RP1151), on the general problem of flow in channels, is based on the modern theory of turbulence and, in particular, on the formulation of this theory which has proved its utility in the study of flow in circular pipes. The formulas

* Communicated by the Director.

for velocity in open channels, and to a certain extent those for velocity distribution, are derived in forms almost identical with those for circular pipes. Using Bazin's test data, the applicability and utility of these formulas are established.

It is also shown how the Manning formula, one of the earlier type now in common use, is an approximation to the rational form which is valid throughout a certain restricted range of conditions.

SURFACE TREATMENT FOR PROTECTING STEEL AGAINST CORROSION.

Some of the factors affecting the protective value of paints for steel and galvanized surfaces are being studied at the Bureau, using accelerated laboratory corrosion tests supplemented by outdoor exposure. When steel is used in the form of light-gage sheet, protection is a matter requiring serious consideration, particularly in inaccessible locations, such as the interior of walls. An important part of the present investigation is a laboratory study of the conditions affecting the durability of paint films on steel and galvanized surfaces under conditions somewhat similar to those which might be encountered in service. Special attention is being given to the severity of corrosion resulting from condensed moisture. Painted steel and galvanized metal panels are being tested in the accelerated weathering apparatus, salt spray, and in a condensation corrosion chamber. Similar panels are also exposed outdoors on the roof of the Chemistry Building. Numerous pretreatment solutions for both galvanized metal and plain steel, with about 60 priming paints, are included in the investigation.

An account of this work is given in a new Report on Building Materials and Structures, BMS8, now available from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents a copy.

CORRELATION OF ELECTROLYTIC CORROSION TEST WITH ACTUAL CORROSIVENESS OF SOILS.

Recent studies of the corrosion of pipe lines have shown that there is a certain regularity in the occurrence of leaks and that the total number of leaks which has occurred over a long

period of time is related to the soil conditions to which the pipe line has been exposed. The corrosion which has occurred on a pipe line system, measured in terms of the relative length of line that has been repaired, has also been used to express the corrosiveness of a large number of soil types, and to correlate the results of laboratory corrosion tests with the corrosion experienced in practice. An accurate record of leaks and replacements, extending over 45 years, on an extensive pipe line system provided a further opportunity for the investigation of corrosion under actual operating conditions and for correlating these data with the results of an electrolytic test for soil corrosiveness.

This test consists in the measurement of the polarization voltage at various current densities of a specially designed corrosion cell, in which the electrodes are steel and the electrolyte is the soil under test. The cell is constructed in such a way that the process of corrosion is similar to that in nature. The average current density corresponding to a definite range of potential is taken as the measure of the corrosiveness of the soil.

As described in RP1157 by I. A. Denison and R. B. Darnielle in the *Journal of Research* for December, samples of soil representing 27 soil types were collected along the right of way of a 128-mile section of a pipe line system, and their corrosiveness was tested by means of the electrolytic corrosion test. When the values were averaged for each soil type and plotted against the number of leaks which had developed on the pipe line in each of the soil types over an average 33-year period, a rough linear correlation was obtained. According to the criterion used, the relative corrosiveness of the soils along approximately 80 per cent. of the total length of the pipe line was correctly classified.

The influence of certain soil properties on corrosion was indicated by the leak and repair records and by the results of the corrosion test. In a group of associated soils, corrosiveness increased as the drainage became more deficient and as the soil became heavier in texture. The variation in corrosiveness with depth is shown for a number of soil profiles, and has been correlated with the aeration and texture of the soil material.

PROGRESS REPORT ON SILVER RESEARCH PROJECT.

That the great immediate opportunity to develop a tonnage use for silver lies in the field of corrosion-resistant containers is one of the important conclusions in the Seventh Progress Report of the Research Project on New Industrial Uses for Silver. This report, released November 1, 1938, like earlier ones (*Technical News Bulletins* 244, 249, 252, and 254 (August, 1937, and January, April, and June, 1938)), has been prepared in mimeograph form for distribution to the sponsors and interested parties. As previously mentioned in this *Bulletin*, the Project is sponsored by a group of leading American silver-producing companies, and has its headquarters at the National Bureau of Standards.

According to the report, a survey has shown that a real need exists for cans, barrels, and other shipping containers more resistant to corrosive attack than some present types in use in the chemical industry, in the canning of certain food products and beverages, in the pharmaceutical, and in the essential oil industries. While canned goods as packaged and marketed today reach the ultimate consumer in wholesome condition, improvement in flavor or color, for example, is still possible for some commodities. In the chemical and allied industries, the containers used in shipping, as well as in the manufacture and storage of chemical products, present troublesome problems. Silver has a remarkable resistance to corrosion by (and, in a corollary manner, to contamination of) foodstuffs and beverages; its chemical inertness to caustic alkalies, to organic acids, and to certain mineral acids and salts is now widely appreciated. According to the survey made by the Project, the development of silver-lined containers adaptable to the uses indicated would open up a large potential market for such containers. Statistics available show that if these containers can be manufactured at a reasonable cost the silver requirement for only those applications now known to the Project staff would total some millions of ounces.

If the cost of the containers, etc., is to be within commercially acceptable limits it is evident that the silver must be applied as a relatively thin coating or lining. Two methods of producing such "coatings" of silver are known to offer a

means of obtaining the corrosion resistance of silver at a price probably within commercial limits for specific applications now being investigated. These methods are (*a*) electroplating, and (*b*) fabrication from silver-clad base metal.

Coöperative work between a commercial can manufacturer, a supplier of silver-clad copper and steel, and the Project staff has led to the production of an experimental 12 ounce container for chemicals fabricated from copper or steel sheet 0.012 inch thick which was clad with 0.001 inch thickness of silver. The first of these cans was made some months ago, and since that time attention has been devoted to the possible production of silver-lined cans at a lower cost, especially larger sizes and other types of can, and to the development of silver-lined barrels.

Naturally the container field is a very broad one, and the research program is concerned with a variety of problems. Silver coatings being investigated may be roughly classified as follows:

Approximate silver thickness	Possible applications
0.0002 inch or less	Food and beverage cans
.002	Shipping containers, barrels, etc.
.02 and up	Chemical apparatus, silver bearings for aviation engines, etc.

All possible methods of applying silver coatings are being investigated. A silver plating plant has been installed at the Bureau under the supervision of Dr. William Blum, chief of the Electrochemistry Section, to permit pilot-plant operating conditions and the electroplating of material for coöperative tests with industrial concerns interested in developing silver-lined containers. Messrs. C. S. Lowe and A. C. Simon have been recently added to the Silver Research Project staff at the Bureau and are devoting their full time to this work. Attention is also being devoted to methods of fabricating and joining silver-lined containers, and to studying the corrosion resistance of silver, silver-coated base metal, and silver-soldered joints when exposed to certain products which industry contemplates shipping in these containers.

In the case of silver alloys, the metallurgical program has advanced to the point where tensile test data have been obtained showing the effect of small additions of silver on the properties of a number of commercial alloy types. Were silver as low priced as the more common alloying elements, in many instances the improvement in properties resulting from addition of a small percentage of silver would be of great practical interest. At the present price of silver, each per cent. of silver added increases the cost of the alloy 6¼ cents per pound. The improved properties commented on below must be balanced against the cost of the silver needed for the improvement, and there is, therefore, the question of practical value to be kept in mind. Attention is called here to the more interesting results obtained, without attempting at this time to evaluate the commercial importance of the data. The data on which the observations are based appear in that part of the Seventh Progress Report prepared by the research associates at the National Bureau of Standards.

The following alloys showed that adding 5 per cent., or somewhat less, silver notably increased the yield strength of the wrought alloy without commensurate loss in ductility: 80–20 cupro-nickel, alpha brasses, 5 and 10 per cent. tin bronzes, 5 per cent. aluminum bronze, and Everdur (3 per cent. Si, 1 per cent. Mn) bronze.

The 10 per cent. tin bronze, the manganese-silicon bronze and the 5 per cent. aluminum bronze were markedly improved by adding 3–5 per cent. of silver to the alloy. In these instances the silver addition induces a response to precipitation hardening heat treatment, although some improvement was observed even without special heat treatment.

Approximately 5 per cent. silver added to the wrought eutectic aluminum silicon alloy conferred substantial added hardness at temperatures above the softening temperature of the silver-free alloy. It is expected from the data obtained to date, that silver will be found to improve the high temperature properties of aluminum-rich alloys in general, as well as in the case of the Al-Si alloy mentioned.

Lead-silver soft solders (5 per cent. silver) have been found to make satisfactory sweated joints in copper tubing assemblies, and such joints have good properties when tested at elevated temperature for long periods of sustained loading.

The research on fungicidal properties of silver compounds at Cornell University has demonstrated the possibility of using a silver spray as a protectant fungicide. Success in this development promises an outlet of some magnitude for silver, and encouraging results are being obtained, since the silver spray solution appears as effective as Bordeaux mixture while possessing some advantages, and being of comparable cost.

The research at Battelle Memorial Institute on bearings has brought out advantages which a silver lead alloy (4–6 per cent. lead) seems to offer when compared with pure silver. Effort is now being made to prepare steel-backed bearings of this alloy by electrodeposition methods.

Research is continuing at Rensselaer Polytechnic Institute on sliding silver contacts. A performance comparison has recently been made between latest model starter motors equipped with copper-graphite and silver-graphite brushes.

A study of temperature-pressure and time relationships in the cold-welding of silver has been completed at Lehigh University. Cold-welding was observed at temperature as low as 200° C.

CONCRETE AS PROTECTION AGAINST X-RAYS.

Although the danger of prolonged exposure to X-rays was recognized soon after their discovery by Rœntgen, many of the early workers in this field suffered injury before it was learned that a worker could protect himself by interposing proper screens between himself and the X-ray tube. The denser the screening material the greater was the degree of protection observed for screens of equal thickness. For this reason lead came into common use as a protective material, both in metallic form and in combination with other substances, as in lead glass and lead rubber. The penetrating power of the X-radiation in common use has increased very much in recent years; with this trend lead screens of increasingly greater thickness were required until today the cost of lead for protection against the more penetrating radiation may be a considerable part of the total cost of the X-ray installation. The cost of the lead itself is only a part of the expense of lead protection, since elaborate supporting sub-

structures are required. Moreover, few existing hospitals or laboratory buildings can take the additional load.

Since new buildings must in most cases be built, or old structures remodeled and reinforced, and since such construction is usually in concrete, the possibility of using concrete both as a structural material and as a protective barrier suggests itself. In a recent study by George Singer, L. S. Taylor, and A. L. Charlton, reported in the December *Journal of Research* (RP1155), the protective properties of a selected group of prepared concrete samples and commercial building blocks were determined. It was found that the protective qualities did not depend upon the nature of the concrete mix but only on the mass of the barriers. Furthermore, the protective value of concrete was greater for X-rays of greater penetrating power, so that the concrete thickness required for protection at 400 KV. was only slightly greater than that required at 200 KV. Curves for calculating the thickness of concrete needed for complete protection were obtained.

In any case, however, the weight of the concrete required was found to be greater than that of lead for the same degree of protection, but this is no serious disadvantage since concrete is cheap and requires no external supports. For the more penetrating radiation concrete is a protective material of considerable merit.

PORTABLE GEIGER COUNTER UNIT.

A portable instrument for measuring the strength of radium preparations, surveying radium dial painting plants, examining radioactive ores, and for detecting lost radium has been developed by L. F. Curtiss of the Bureau's Atomic Physics, Radium, and X-rays Section. The complete instrument weighs only 13 pounds and is entirely self contained, so that it can be used anywhere.

The instrument employs an integrating counter circuit, operated by dry cells carried in the case. Recent tests of the circuit show that it is sensitive to one millionth of a gram of radium at a distance of one meter, and as it is capable of more or less accurate calibration, quantitative results are possible.

As an aid in locating lost radium, the instrument should be

particularly valuable since it can detect one milligram (a very small medical preparation) at about 30 meters.

For a complete description of the apparatus, RP1154 in the December number of the *Journal of Research* should be consulted.

IONOSPHERE CHARACTERISTICS FOR HALF A SUNSPOT CYCLE.

The sun is the principal source of the energy which produces the ionization of the earth's upper atmosphere. Changes in solar activity, as manifested by changes in sunspot numbers, in general, produce corresponding changes in the ionization of the various layers of the ionosphere, and consequent changes in the characteristics of radio sky-wave transmission. A paper (RP1159) by Newbern Smith, T. R. Gilliland, and S. S. Kirby in the *Journal of Research* for December shows that the increase of sunspot numbers, from the minimum of 1933, to 1938 has been accompanied by a general increase in the values of the critical frequencies of the ionosphere layers. In the case of the E layer, there has been good general correlation between critical frequency and sunspot numbers, the former increasing to $1\frac{1}{4}$ times the value it had at the sunspot minimum. In the case of the F_2 layer, the correlation has not been so good in detail, and the increase in its critical frequency has been much larger. The critical frequency reached a value twice as great as at the sunspot minimum.

The long-period increases in sunspot numbers and critical frequencies are studied in some detail in the graphs of this paper, and the regular diurnal and seasonal variations in critical frequencies are also summarized. The short- and long-period variations in ionosphere characteristics appear to be so well marked as to suggest the possibility of forecasting the average condition of the ionosphere and radio transmission conditions, months and even years in advance.

R.C.A. Institutes Announces Television Courses.—In announcing its eagerly awaited courses in Television Engineering R.C.A. Institutes makes available to the public an extension of its educational facilities. Stabilized by thirty years' experience in teaching exclusively the technical side of radio, R.C.A. Institutes has maintained a conservative attitude throughout the recent years of enthusiasm for this new mode of communication. Feeling that the basic system of television is unlikely to undergo any immediate major change R.C.A. Institutes considers the time propitious for the inception of its Television Courses. These courses will begin with the fall term. For persons who have had no previous training in Radio Engineering the course requires a period of two years in the day school or five years in the evening school. Special Television Units of six months' duration in the day school or one year in the evening school are available to applicants possessing adequate technical background. R.C.A. Institutes is a member of the RCA family. This relationship inherently endows R.C.A. Institutes with unequalled facilities for technical radio instruction.

R. H. O.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, DECEMBER 21, 1938.

The regular monthly meeting of The Franklin Institute was called to order at 8:15 o'clock, by Mr. W. Chattin Wetherill, Vice-President.

The minutes of the November meeting were approved as printed in the December issue of the Journal.

The Chairman then announced that the additions to membership since the last meeting were as follows:

Active	22
Associate	39
Student	39
Total	100

He then called upon the Secretary for further business.

In accordance with ARTICLE IV, Section 4, of the By-Laws, the Secretary read the following nominations for Officers and Managers for the term beginning January 1939:

President
(to serve one year)
Philip C. Staples

Vice-Presidents
(to serve one year)
Walton Forstall
W. Chattin Wetherill
S. S. Fels

Treasurer
(to serve one year)
Benjamin Franklin

Members of the Board of Managers
(to serve three years)
Edward G. Budd
Clarence A. Hall
A. Atwater Kent
William Fulton Kurtz
Richard W. Lloyd
O. J. Matthews
George W. Pepper
James S. Rogers

Dr. Barnes called attention to the James Mapes Dodge Christmas lectures, which are scheduled for the afternoons of December 28, 29 and 30. Dr. Hugh Stott Taylor of Princeton, New Jersey, will be the speaker and his subject will be "Chemistry for Young Citizens."

The Chairman then introduced Dr. Ellice McDonald, Director of The Biochemical Research Foundation of The Franklin Institute, who presented his third annual Report on the work of the Foundation. He gave an account of the activities of the Foundation and the researches which are at present being conducted and a number of the problems connected with diseases and processes of diseases. Information was given concerning the new department of Physical Chemistry with some of its accomplishments by means of new apparatus. Refer-

ence was also made to further work with the Cyclotron. A number of other problems were also discussed. The subject was illustrated by lantern slides.*

On motion of Dr. G. H. Meaker a rising vote of thanks was extended to Dr. McDonald for his interesting Report.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, December 14, 1938.)

HALL OF THE COMMITTEE,
PHILADELPHIA, DECEMBER 14, 1938.

MR. EDWARD L. FORSTALL *in the Chair.*

The following reports were presented for final action:

No. 3045: Vari-Speed Control.

This report recommended the award of a Certificate of Merit, jointly, to Percy Russell and E. Burke Wilford of Philadelphia, Pennsylvania, "In consideration of the development and application of a simple means of regulating and controlling the speed of small electric motors."

No. 3060: Evaporated Metal Films for Astronomical Mirrors.

This report recommended the award of two Edward Longstreth Medals, one to John Strong, of the California Institute of Technology, and one to Robley C. Williams, of the University of Michigan, "In consideration of their independent development and improvement of a process for coating astronomical mirrors with a layer of metallic aluminum deposited thereon by evaporation in vacuo."

JOHN FRAZER,
Secretary to the Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections of the Institute any technical writings of members who have had occasion to publish such material.

Literary contributions from author-members will be gratefully acknowledged, properly inscribed and noted in the Journal of the Institute.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 8½ × 11 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays two until ten o'clock P.M. 696 readers made use of the facilities during the twenty-five days of November.

AGRICULTURE AND FORESTRY.

ALLEN, SHIRLEY WALTER. An Introduction to American Forestry. First Edition. 1938.

---

* See page 59.

ARCHITECTURE AND BUILDING.

American Gas Association. Comfort Heating. 1938.

DALZELL, J. RALPH, AND CHARLES L. HUBBARD. Air Conditioning, Heating and Ventilating. 1938.

GERBEAUX, H. Le Remplacement des Rivets par la Soudure dans la Charpente Métallique. n.d.

ASTRONOMY.

BARTON, WILLIAM H., AND JOSEPH MARVON JOSEPH. Starcraft. 1938.

AVIATION.

PHILP, CHARLES G. Stratosphere and Rocket Flight. Third and Revised Edition. 1937.

WEEMS, P. V. H. Air Navigation. Second Edition. 1938.

BIOGRAPHY.

NEHER, F. L. Röntgen: Roman eines Forschers. 1936.

TATE, ALFRED O. Edison's Open Door. 1938.

BIOLOGY AND BIOCHEMISTRY.

GORTNER, ROSS AIKEN. Outlines of Biochemistry. Second Edition. 1938.

SCHMIDT, CARL L. A. The Chemistry of the Amino Acids and Proteins. 1938.

WILLIAMS, ROBERT R., AND TOM D. SPIES. Vitamin B_1 (Thiamin) and its Use in Medicine. 1938.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

BRADSTREET, R. B. The Standardization of Volumetric Solutions. 1938.

DEFIZE, J. C. L. On the Edeleanu Process for the Selective Extraction of Mineral Oils. 1938.

ECKLES, CLARENCE HENRY, WILLES BARNES COMBS, AND HAROLD MACY. Milk and Milk Products. Second Edition. 1936.

ELLIS, OLIVER C. DE C., AND WILLIAM A. KIRKBY. Flame. 1936.

FIENE, F., AND SAUL BLUMENTHAL. Handbook of Food Manufacture. 1938.

FIERZ-DAVID, HANS EDUARD, AND LOUIS BLANGEY. Grundlegende Operationen der Farbenchemie. Vierte umgearbeitete und vermehrte Auflage. 1938.

Institution of Fire Engineers. Chemical Fires and Chemicals at Fires. 1938.

KEANE, CHARLES A., AND P. C. L. THORNE, ed. Lunge and Keane's Technical Methods of Chemical Analysis. Second Edition. Volumes 1 and 3. 1924–1931.

LÁZÁR, CHARLES. Manual of Cosmetics. 1938.

MEYER, HANS. Analyse und Konstitutionsermittlung organischer Verbindungen. Sixth edition. 1938.

NOYES, ARTHUR A., AND MILES A. SHERRILL. A Course of Study in Chemical Principles. Second Edition, Rewritten. 1938.

Porcelain Enamel Institute. Proceedings 1–2 Forum. 1937.

SCHREINEMAKERS, F. A. H. Lectures on Osmosis. 1938.

SOULE, BYRON A. Library Guide for the Chemist. First Edition. 1938.

SWIETOSLAWSKI, WOJCIECH. Ebulliometry. The Physical Chemistry of Distillation. 1937.

ECONOMICS.

KEMMERER, EDWIN WALTER. Money. 1935.

ELECTRICITY AND ELECTRICAL ENGINEERING.

American Radio Relay League. Radio Amateur's Handbook. Sixteenth Edition. 1938.

ARCHER, GLEASON L. History of Radio to 1926. 1938.

EASTMAN, AUSTIN V. Fundamentals of Vacuum Tubes. First Edition. 1937.

GATTY, O., AND E. C. R. SPOONER. The Electrode Potential Behaviour of Corroding Metals in Aqueous Solutions. 1938.

HALL, EDWIN HERBERT. A Dual Theory of Conduction in Metals. 1938.

LOEB, LEONARD B. Fundamentals of Electricity and Magnetism. Second Edition. 1938.

Radio Handbook by the Editors of "Radio." Fifth Edition. 1938.

ROGET, S. R. Dictionary of Electrical Terms. Third Edition, Revised and Enlarged. 1938.

ST. JOHN, THOMAS M. Real Electric Toy-Making for Boys. Third Edition. 1905.

ENGINEERING.

BISHOP, CARLTON THOMAS. Structural Design. 1938.

BURT, HENRY JACKSON. Steel Construction. Revised by C. H. Sandberg. 1939.

JENKINS, RHYS. Collected Papers. 1936.

RUBEY, HARRY. Route Surveys. 1938.

FORGING AND WELDING.

JOHNSON, CARL G. Forging Practice. 1938.

KEHL, ROBERT J. Oxyacetylene Welding. Revised by Morgan H. Potter. 1939.

POTTER, MORGAN H. Electric Welding. 1939.

GEOLOGY.

CROWTHER, J. G. About Petroleum. 1938.

MANUFACTURES.

HERZOG, R. O. & F. OBERLIES. Technologie der Textilfasern, VI Band, 1 Teil; VIII Band, 3 Teil, B. 1938.

Institution of the Rubber Industry. Annual Report on the Progress of Rubber Technology. Vol. 1. 1937.

PATTOU, ALBERT BRACE, AND CLARENCE LEE VAUGHN. Furniture, Furniture Finishing, Decoration and Patching. 1938.

MATHEMATICS.

JAHNKE, EUGEN, AND FRITZ EMDE. Tables of Functions with Formulae and Curves. Third (Revised) Edition. 1938.

VAN HORN, C. E. A Preface to Mathematics. 1938.

MECHANICAL ENGINEERING.

Institution of Mechanical Engineers. Proceedings of the General Discussion on Lubrication and Lubricants, 1937. Two volumes. n.d.

METALLURGY.

MARSH, J. S. The Alloys of Iron and Nickel. Vol. 1. Special-Purpose Alloys. First Edition. 1938.

ROSENHOLTZ, JOSEPH L., AND JOSEPH F. OESTERLE. The Elements of Ferrous Metallurgy. Second Edition. 1938.

PHOTOGRAPHY.

Photographie 1939. 1938.

U. S. Camera 1939. 1938.

PHYSICS.

BLAIR, G. W. SCOTT. An Introduction to Industrial Rheology. 1938.

Grimsehls Lehrbuch der Physik—Neubearbeitet von Professor Dr. R. Tomaschek. Zweiter Band, erster Teil; Elektromagnetisches Feld-Optik. Achte Auflage. 1938.

HIRSCHLAFF, E. Fluorescence and Phosphorescence. 1938.

LUCKIESH, MATTHEW. Color and Colors. 1938.

ROJANSKY, VLADIMIR. Introductory Quantum Mechanics. 1938.

THOMPSON, H. W. A Course in Chemical Spectroscopy. 1938.

RAILROAD ENGINEERING.

Association of American Railroads—Mechanical Division. Locomotive Cyclopedia of American Practice. Tenth Edition. 1938.

SCIENTIFIC ESSAYS.

Royal Society of Edinburgh. Transactions. Volume 59, Part 2. 1938.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Proteinase Secretion and Growth of Clostridium histolyticum.—WALTER KOCHOLATY, LEOPOLD WEIL, AND LOUIS SMITH (*Biochemical Journal*, **32**: 1685, 1938.) The proteolytic enzymes of a dissociated strain of *Cl. histolyticum* were found to be secreted directly into the medium in which the organisms were grown, very little enzyme remaining within the bacterial cells. Both the number of bacteria present and the enzymatic activity of the medium were highest about twenty-four hours after inoculation.

The proteolytic enzymes of this organism decomposed gelatin, clupein, and casein. The decomposition of these proteins was accelerated in the presence of Fe^{++} and cysteine.

The enzyme deteriorated quite rapidly if kept in the presence of the organisms at 37.5° C. If the organisms were removed, the rate of deterioration at this temperature was much lower. There was little or no deterioration of the enzyme, if it was kept sterilely at 4° C.

Studies on the Endo-enzymes, Particularly the Peptidases, of Clostridium histolyticum.—WALTER KOCHOLATY, LOUIS SMITH, AND LEOPOLD WEIL. (*Biochemical Journal*, **32**: 1691, 1938.) The endo-enzymes were obtained by treating the bacteria in a supersonic oscillator. A treatment of 20 minutes resulted in the disruption of 80–85 per cent of the cells, releasing the endocellular enzymes into the medium in which the bacteria were suspended.

The solutions obtained by this method contained a dipeptidase with a pH optimum of 7.6, and a polypeptidase with a pH optimum of 8.7. The polypeptidase was activated by Mg^{++}, but the dipeptidase was not affected. Leucylglycine and leucylglycylglycine were the substrates employed.

The disruption of the bacterial cells also yielded enzymes which brought about the deamination, at pH 7.8, of glycine, *l*-leucine, *d*-alanine, *d*-glutamic acid and *l*-tryptophan, with the liberation of NH_3.

All attempts to demonstrate the presence of a bacterial carboxy-peptidase were negative. No dipeptidase, amino-polypeptidase, or deaminase was found in the cell-free filtrates of young, rapidly growing cultures. Evidently, these enzymes are strictly endocellular.

Enzymatic Adaptation in Clostridium histolyticum.—WALTER KOCHOLATY AND LEOPOLD WEIL. (*Biochemical Journal*, **32**: 1696, 1938.) Using a dissociated strain of *Cl. histolyticum*, it was found that certain properties of the proteolytic enzymes are determined by the conditions under which the bacteria are grown. If the organisms were cultivated in a medium of pH 7.2–7.4, the optimum pH for the action of the enzyme was about pH 7.0. If the pH of the culture medium was allowed to drop, during incubation, to 5.8, the optimum pH for the enzyme was about 6.0.

These organisms, grown on ordinary media, produced enzymes which digested both casein and gelatin. If, however, the organisms were grown in casein for many generations, they became adapted to this protein, and the enzymes were activated by Fe^{++} and cysteine. Bacteria cultivated for many generations on gelatin exhibited a similar phenomenon. In this case, the enzymes produced attacked gelatin but did not attack casein unless they were activated.

By culturing the casein-adapted bacteria on a gelatin medium supplemented by those amino acids present in casein but not in gelatin (*d*-valine, *l*-tyrosine, *l*-tryptophan, *d*-hydroxyglutamic acid), an enzyme was produced which attacked both proteins. The same result was achieved by growing gelatin-adapted bacteria on casein supplemented by amino acids missing in this protein but present in gelatin.

BOOK REVIEWS.

ATOMIC STRUCTURE, by Leonard B. Loeb. 445 pages, illustrations, 15 × 24 cms. New York, John Wiley & Sons, Inc., 1938. Price $4.50.

The very mention of the title of this book brings to mind the rapid progress in knowledge of atomic structure that has been made in the past three decades. We have learned that things are not so simple, definite, and final as they seemed to be previous to this period. The groping further and further into the infinite and infinitesmal reveals an increasingly greater complexity that requires for an understanding a far more thorough and wider background. Just how to obtain this is the problem of the educator. The author of this book believes that it is impossible to introduce the subject directly from the rather abstract and modern wave mechanical viewpoint. In order to give a good understanding it is believed that the student should grow into the modern developments much the same way as the physicists who have developed the field have done.

Accordingly the subject is developed on an essentially experimental and historical basis, giving due respect to the fragmentary and incomplete experimental bases of modern formulations. There are four parts to the text. In the first the work of J. J. Thompson is discussed on the formulation of the atom which leads up to the scattering experiments of Rutherford and the reformulation of ideas necessary for the development of the Bohr theory. The nuclear atom is the second part of the book. It treats on its topic by the assumption of stationary non-radiating orbits with regard to the simple H atom drawing the classical quantum theoretical conclusions. Then an introduction is given to the formal general classical procedure of quantization which is followed by the vector model, the diverse studies which bear upon electron spin such as the Zeeman effect, and the construction of the atom from the four quantum numbers and the Pauli exclusion principle.

This is in preparation for part three of the book. Here the electrical properties of atoms is taken up. It is introduced by means of the Franck and Hertz experiments and proceeds through photoelectric excitation and ionization, and excitation and ionization by electron impact. Molecular structure and behavior, the electrical behavior of molecules—band spectra, and the fundamental electronic, ionic, and atomic reaction complete this part. The final and fourth part of the book is devoted to the electron theory of metals in which there is a brief presentation of the modern wave mechanical theory of the metallic state.

The work is a vigorous text of college grade requiring a mathematical prerequisite of the calculus. It is basic in preparation for further study of atomic structure, it lays the physical foundation for a study in wave mechanics and it prepares for work in the field of electronics and discharge in gases.

R. H. OPPERMANN.

A PREFACE TO MATHEMATICS, by C. E. Van Horn. 124 pages, illustrations, 13 × 20 cms. Boston, Chapman and Grimes, Inc., 1938.

Here is a book directed especially at teachers—teachers of mathematics, although it does contain information valuable to everyone. Much basic informa-

tion is often overlooked in the rush to absorb subject matter when studying and even after absorption is successful to the degree of application, a knowledge then acquired of the definite reason for the study rounds out to a greater degree the motivation of application. It must be conceded that if one were to pause before attempting to take up the study of any subject, to determine what is the reason for studying it and form a definite purpose, an aim, or goal, then greater interest in the subject will be had resulting in a better understanding. To be a good teacher of a subject like mathematics it is necessary that this be kept in mind. It will eliminate the class of teachers who are likened to the machinist who works from whistle to whistle on a small but important part of a great mechanism but who has no knowledge whatsoever of where it belongs or what part it plays in the completed machine. He is merely a human cog, and not such a good one at that.

The book presents unusual material, in an unusual way. As a foundation there are outlined what general essentials are needed for a teacher such as bigness of mind, zeal according to knowledge, high devotion, development of personality etc. The book proceeds to give definite and accurate and varied information as to the usefulness and significance of mathematics, a knowledge that makes a better teacher of the subject. In doing this, topics like, "Why study mathematics?", and a clear view of the differences between algebra and arithmetic, are discussed. Suggestions on the teaching of pure geometry and analytical geometry are given as well as a means for building up in the student's mind conceptions both of the diverse forms and of the fundamental role of functions in mathematics. Considerable space is devoted to the calculus presenting some of the principles of it relating to its four fundamental concepts: limits, derivatives, antiderivatives, and definite integrals. The last part of the book is on the question of "What is mathematics." In it an attempt is made to present a view of its significance in the world of human knowledge. It acts as a challenge to the reader to build some philosophy of mathematics—a valuable background for the teacher.

R. H. OPPERMANN.

A DUAL THEORY OF CONDUCTION IN METALS, by Edwin Herbert Hall. 170 pages, illustrations, 14 × 21 cms. Cambridge, The Murray Printing Company, 1938. Price $2.00.

Ever since electricity was made to flow through metallic conductors various theories were advanced as to the mechanism of flow. Undoubtedly this was coupled directly with the problem of the nature of electricity because a knowledge of the mechanism of flow may indicate to some degree at least the substance if such it be. Probably the best known theory of movement at present is that of free electrons having the thermal energy of monatomic gas particles, moving among the atoms of the metal. Another theory is that of corpuscles going straight out of one atom and lodging at their first impact in another without getting into temperature equilibrium with their surroundings. Both of these are attributed to J. J. Thompson some three decades ago.

The author of this book, shortly after, suggested that these two theories may be combined so that electric currents may be maintained and so that all the known effects of electrical and thermal conduction in metals be produced. Little interest was taken in this at the time but now reference to it is being made. With this in mind the author herewith presents this work which sets forth an attempt

to discover, and in a manner to account for, numerical relations existing between electrical conductivity, thermal conductivity and thermoelectric properties in a considerable number of metals, with the belief that these numerical relations, even if the formulas expressing them are to be regarded as purely empirical, are worth recording in permanent form.

The method of presentation is praiseworthy. Assumptions are made freely but carefully labled and just as freely discarded when their use has expired and the point made. There is much to commend the theory here exposed. In this day of close scrutiny and investigation not only physicists but engineers should examine this theory as a contributive suggestion on a subject of very great importance to physics which of course results in the practical application of engineering.

R. H. OPPERMANN.

GRIMSEHLS LEHRBUCH DER PHYSIK, by Dr. R. Tomaschek. Zweiter Band, Erster Teil, 866 pages, plates, illustrations, 15 × 23 cms. Leipzig, B. G. Teubner, 1938. Price 26 R.M.

This book is Vol. II, Part I, of the well known set of books devoted to the general subject of physics. It is restricted to the topics of the electromagnetic field and optics. Various books belonging to this set have been reviewed in these columns before and those who are familiar with them will have noted an outstanding feature of thoroughness of treatment. This book is no exception. It is the eighth edition, presenting the subject from the modern conception of fundamentals as they are known to be at present in the entire scope of the topics discussed. Under the electromagnetic field, to which the first part of the book is devoted, the electrostatic field is the basis for the discussion of magnetic conditions in the ether and the magnetic field of the earth. From this there is built a general treatment on magnetism and electrical induction from the collapse of a magnetic field and the proof and determination of the strength of current. This is carefully examined in all of its phases including the connection between the current and the field, the current and voltage, the mechanism of flow and the conductance of electricity in gases and vacuum, as well as through metals.

Electromagnetic induction is introduced by way of the alternating field. Here stress is laid on materials susceptible to magnetism and the nature of magnetism generally, its effects and its field with respect to various shapes and forms of the material. This leads directly to a stronger treatment on induction principles from which there is evolved alternating current generation and its action in induction power apparatus. Electromagnetic vibration and waves next taken up are subjects which bring the reader back into the realm of the ether.

The second part of the book, devoted to optics, starts with a discussion on light in general, its radiation, reflection and intensity. Considerable time and space are then devoted to geometrical optics in quite some detail, which is followed by a treatment of equal length, on light waves and the speed of light. Polarization of light and a brief coverage of physiological optics complete the book.

The book contains innumerable illustrations, both in drawings and photographs. There is an author and comprehensive subject index. The coverage is elementary and complete insofar as it goes. The book of course is restricted to those having a good knowledge of the German language.

R. H. OPPERMANN.

ELEMENTS OF FERROUS METALLURGY, by Joseph L. Rosenholtz and Joseph F. Oesterle. Second Edition, 258 pages, plates, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1938. Price $3.00.

This is the second edition of a work presenting an elementary treatment of the subject unencumbered by minute detail. The authors state that they feel there is a definite need for a book of this size and character. Certainly engineers of all kinds should be at least familiar with the subject for it is fundamental. It has cultural value even if such knowledge is never put to practical use. The second edition, of course brings the treatment up to date and includes revisions of the nature of new approaches and arrangements as well as the inclusion of new practices, alloys and theories which have been advanced since the publication of the first edition.

The treatment begins with a discussion on the ores of iron and what they are, the chemical reactions of oxidation and reduction, and a description of the various metallurgical fuels. Then there is given a description of the blast burnace, its process and its product, pig iron, which is followed by the Bessemer Process, the Open-Hearth Process and the Electric Process. Wrought iron, the material for the Cementation Process is next treated before a brief mention of the process itself. The Crucible Process is likewise covered. Subsequently there is examined in logical order the natural changes experienced by the metal during solidification, the iron-carbon system, the mechanical treatment of steel, the heat treatment of carbon steels, alloy steels, and cast irons. The concluding part of the book is devoted to the methods used in the foundry for the production of both iron and steel castings.

Being elementary, the treatment is almost entirely explanatory which fits well with the purpose. Sufficient coverage is made so that one coming in contact with ferrous metallurgy has a background which will enable immediate further study. The book is well illustrated and contains an index. It is an excellent means of improving general knowledge as well as a means of reference to those who do not have directly to do with the subject.

R. H. OPPERMANN.

TABLES OF FUNCTIONS WITH FORMULÆ AND CURVES, by Dr. Eugen Jahnke and Fritz Emde. Third Edition, 303 pages, illustrations, 16 × 24 cms. Leipzig, B. G. Teubner, 1938. Price 15 R.M.

Here is the third edition of a book which contains data useful to a great many who use mathematics to any extent. Its use is considerably enhanced by being printed both in German and English between the same cover. In fact whenever a statement is made in one of these languages there appears a translation to the other either beneath it or alongside. The contents cover Sine, cosine and logarithmic integral; Factorial function; Error integral and related functions; Theta-functions; Elliptic integrals and functions; Legendre functions; Bessel functions; Riemann Zeta-Function; Confluent hypergeometric functions; Mathieu functions. An interesting and valuable feature is a bibliography on every feasible section of the book.

R. H. OPPERMANN.

ELEMENTARY SURVEY OF PHYSICS, by Arthur E. Hass with the collaboration of Ira M. Freeman. 203 pages, illustrations, 13 × 20 cms. New York, E. P. Dutton & Co., Inc., 1938. Price $1.90.

There is an increasing need in these times of advancing scientific achievements for a means of interpretation through which a person not intimately associated with technical matters can gain an appreciation of them. Current thought is approaching the point of questioning the relation between science and social progress and certainly no intelligent perusal can be made of this subject without some knowledge of science in general. It is therefore imperative that for a well rounded education it is necessary to have an understanding of some of the fundamentals of scientific subjects.

The Survey of Physics was written for this purpose. The tenor of the work is non-mathematical and descriptive, yet it covers the elements of the subject. It is not by any means a short-cut or royal road to the mastery of the subject, neither is it written for easy reading by those of the lower grades of education. Those between these limits will find here a book surveying the present day aspects of the subject which is done in a matter of fact way wasting little space for anything but that bearing directly on the subject.

The book opens with a discussion on mechanics and acoustics, covering solids, liquids, and gases, then dealing with vibrations and waves. The second part deals with heat, general and thermal principles, and change of state. After these, there are parts on optics covering ray optics, wave optics and spectroscopy; and electricity involving electromagnetism, electric current, and the electrical nature of matter. The first appendix is of the character of an article on physics and civilization, which is informative historically. Then there is a supplement for pre-medical students. For such students there is revealed the many ways that physics enters into the medical field. There is also a third brief appendix presenting a few important but simple mathematical deductions and formula.

To cover the subject adequately, and this book does, it is essential that in the space allotted only brief presentations of all the subdivisions can be made. The result of this is the absolute need of reading slowly in order to allow impression of the subject matter.

As a text the book is excellent. As a means of general information on the subject it should appeal to certain classes of readers. As a book for reference it should have wide application.

R. H. OPPERMANN.

THE SUN, ITS PHENOMENA AND PHYSICAL FEATURES, by Giorgio Abetti, translated by Alexandre Zimmermann and Frans Borghouts. 350 pages, illustrations, 14 × 23 cms. New York, D. Van Nostrand Company, Inc., 1938. Price $5.00.

The importance of a knowledge of solar phenomena is readily recognized today as having an influence, direct and indirect, in many diverse fields affecting human activities. To name a few, there is the great field of agriculture, radio and wire communication, chemical substances such as helium, and the health and life of human beings. The sun has been the object of veneration for ages but like other concentrated studies, it has only been comparatively recently that investigation has revealed information for practical application.

The book at hand is a translation from the Italian Il Sole by Giorgio Abetti. It is a presentation setting forth what methods are employed for studying the sun and what results have been obtained up to the present time. To follow it requires only a knowledge of the rudiments of physics and mathematics so that it may be classed as a book of a semi-popular nature. The amateur as well as the professional will find it interesting. Modern ideas of the physics of the outer layers of the sun are given as well as a complete account of the complicated facts concerning the spots and markings on the solar surface and their movements.

In all there are eight parts to the book. First there is described how the sun is observed and what is seen on the sun by direct visual and photographic observation, and by spectrographic observation. Then there is told how the outermost envelopes of the sun are studied during eclipses and in full sunlight. Under the heading of physical constitution of the sun there is given an outline of theories. This is followed by a treatment on radiation and temperature of the sun, a comparison between the physical characteristics of the sun and those of fixed stars, and relationships between solar and terrestrial phenomena—the utilization of solar heat. An important feature of the book is the reminder given of the existence of a large body of observational material yet to be investigated.

The book contains some 157 illustrations of various kinds. The photographs are exceptionally praiseworthy and the drawings fit well with the subject matter. Appended is a list of works consulted which may assist the reader who wishes to go more deeply into the subject. A subject and name index completes a very interesting, factual and usable book.

R. H. OPPERMANN.

BLÄTTER FÜR GESCHICHTE DER TECHNIK. Viertes Heft. Schriftleitung: Dr. Ing. L. Erhard. 80 pages, illustrations, 17 × 25 cms. Wien, Julius Springer, 1938. Price 4 R.M.

This booklet contains a number of papers by prominent men on the general subject of technical progress in what previously was Austria, which now is a part of the German Reich. Dr. Ing. L. Erhard, in the opening paper explains that the German government recognizes the general value of technical and scientific developments which result from a liberal attitude in this direction, the great public benefit derived therefrom, and the evaluation of the fundamentals at hand for the construction of a great German country. Prof. Dr. J. Daimer in his contribution reviews Austria's part in the developments in photographic science by going back in history and describing the results of each worker as time went on and showing that Austria can definitely be ranked with the foremost in this field. The life and work of August Musger is reviewed by Prof. Dr. Schrott which is followed by a biographical sketch of Franz Frh. von Uchatius by Ing. E. Kurzel-Runtscheiner. Both of these men made important contributions to Austria's technical development, the former in the field of optics and the latter in military science. On the subject of technical education Prof. Dr. Franz Schnable of Heidelberg presents the story of Ferdinand Redtenbacher, a great engineer and educator.

The rest of the booklet is devoted to the Report of the Austrian research institute and other miscellaneous subjects. The booklet is interesting for several

reasons, chief of which is the survey of definite contributions of this country to science.

R. H. OPPERMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 636, Approximate Stress Analysis of Multistringer Beams with Shear Deformation of the Flanges, by Paul Kuhn. 21 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

The problem of skin-stringer combinations used as axially loaded panels or as covers for box beams is considered from the point of view of the practical stress analyst. By a simple substitution the problem is reduced to the problem of the single-stringer structure, which has been treated in N. A. C. A. Report No. 608. The method of making this substitution is essentially empirical; in order to justify it, comparisons are shown between calculations and strain-gage tests of three beams tested by the author and of one compression panel and three beams tested and reported elsewhere.

Report No. 643, The Aerodynamic Characteristics of Four Full-Scale Propellers Having Different Plan Forms, by Edwin P. Hartman and David Biermann. 9 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

Tests were made of four propellers, with diameters of 10 feet, having different blade plan forms. One propeller (Navy design No. 5868-R6) was of the usual present-day type and was used as a basis of comparison for the other three, which had unusual plan forms distinguished by the inward (toward the hub) location of the sections having the greatest blade width.

It was found that propellers with points of maximum blade width occurring closer to the hub than on the present-day type of blade had higher peak efficiencies but lower take-off efficiencies. This result was found true for a "clean" liquid-cooled engine installation. It appears that some modification could be made to present plan forms which would produce propellers having more satisfactory aerodynamic qualities.

The propellers with the inward location of the points of maximum blade width had lower thrust and power coefficients and stalled earlier than the present-day type.

PUBLICATIONS RECEIVED.

The Oxidation States of the Elements and their Potentials in Aqueous Solutions, by Wendell M. Latimer. 352 pages, illustrations, tables 16 × 24 cms. New York, Prentice-Hall, Inc., 1938. Price $3.00.

The Perception of Light, by W. D. Wright. 100 pages, illustrations, 13 × 19 cms. London, Blackie & Son, Limited. Price 6 s.

Photography, Its Principles and Practice, by C. B. Neblette. Third Edition, 590 pages, illustrations, 16 × 24 cms. New York, D. Van Nostrand Company, Inc., 1938. Price $6.50.

Fundamental Electronics and Vacuum Tubes, by Arthur Lemuel Albert. 422 pages, illustrations, 16 × 24 cms. New York, The Macmillan Company, 1938. Price $4.50.

Theoretical Mechanics, by Carl Jenness Coe. 555 pages, illustrations, 15 × 22 cms. New York, The Macmillan Company, 1938. Price $5.00.

Chemische Gasreaktionen, by Dr. H. J. Schumacher. 487 pages, illustrations, tables, 15 × 23 cms. Dresden, Theodor Steinkopff, 1938. Price 33.75 R.M.

Blätter fur Geschichte der Technik. Fünftes Heft. Schriftleitung: O. O. Prof. Dr. K. Holey. 137 pages, illustrations, 18 × 25 cms. Wien, Julius Springer, 1938. Price 6 R.M.

Standards on Electroacoustics, 1938. 37 pages, illustrations, 15 × 23 cms. New York, The Institute of Radio Engineers, Inc., 1938. Price 50 cents.

Standards on Transmitters and Antennas, 1938. 42 pages, illustrations, 15 × 23 cms. New York, The Institute of Radio Engineers, Inc., 1938. Price 50 cents.

Note sur les Propriétés des Corps Pulvérulents ayant subi des Pressions tres élevées, par M. Jager. Paris, Chimie et Industrie.

The Non-Technical Aspects of Engineering Education, a bibliography compiled by The Cooper Union Library. 10 pages, 16 × 23 cms. New York, The Cooper Union.

Canada, Department of Trade and Commerce, Dominion Bureau of Statistics, Census of Industry, General Manufactures Branch. The Miscellaneous Industries Group in Canada, 1934, 1935 and 1936. 8 pages. Price 25 cents. Forestry Branch. Preliminary Report on the Pulp and Paper Industry in Canada, 1937. 36 pages. Price 20 cents. 2 pamphlets, 22 × 28 cms. Ottawa, Department of Trade and Commerce, 1938.

National Advisory Committee for Aeronautics. Technical Notes: No. 674, Scavenging a Piston-Ported Two-Stroke Cylinder, by A. R. Rogowski and C. L. Bouchard. 43 pages, illustrations. No. 676, Discharge Characteristics of a Simulated Unit Injection System, by Edred T. Marsh. 14 pages, illustrations. No. 677, Tests of a Contra-Propeller for Aircraft, by William M. Benson. 22 pages, illustrations. No. 678, Hydrodynamic and Aerodynamic Tests of Four Models and Outboard Floats (N. A. C. A. Models 51-A, 51-B, 51-C, and 51-D), by John R. Dawson and Edwin P. Hartman. 41 pages, illustrations. 4 pamphlets, 20 × 26 cms. Washington, Committee, 1938.

Technical Drawing Problems, by Frederick E. Giesecke, Alva Mitchell and Henry Cecil Spencer. 93 pages. New York, The Macmillan Company, 1938. Price $2.25.

CURRENT TOPICS.

Oceanographics.—The oceanographic vessel *Culver* has arrived at the Bermuda Islands from England for a five-year survey in connection with the Bermuda Biological Station and the Wood's Hole Oceanographic Institute to measure the oscillation of the Gulf stream. The survey, according to scientists, may avert the next great drought in the United States Mid-West, predicting it in time to avert disastrous results to United States farming, and may also prove an aid to commercial fishermen in determining movements of fisheries in European waters. By definite observations scientists will try to discover what really happens when wind blows over the open ocean. Scandinavian scientists, physicists and oceanographers have been working on this problem from a theoretical stand-point for years, and have been led to the theory that when winds blow upon water in the northern hemisphere, the surface of the water will move in a direction 45 degrees to the right of the wind, and that at a depth below the surface, depending upon the strength of the wind and the latitude of the observation station, the current will gradually turn and be reversed, finally going in the opposite direction to the wind. This theory has not been proved. Other scientists who have worked on the problem on lakes suggest that the action of the water is not entirely according to the Scandinavian theory. This has a direct bearing upon the action of the trade winds. The *Culver* is a converted yacht, 83 feet overall, with a beam of 19 feet, 3 inches. It has a displacement of 100 tons.

R. H. O.

Food Value of Meat Cuts Easily Seen in New Table.—Meat may be selected by the house-wife according to its food value as well as its cost through the use of a new table which shows the approximate average composition of the different cuts from three classes of lamb carcasses. The table, which has just been issued by the United States Department of Agriculture, is one result of a series of meat investigations that have been in progress for 12 years. Through the use of the table, housewives, dietitians, chefs, and others can obtain information concerning the approximate amounts of fat, lean, bone, protein, and water in the different cuts from animals of various degrees of fatness, reports O. G. Hankins, in charge of meat investigations for the Bureau of Animal Industry. The studies show, for example, the average composition of fat, intermediate, and

thin lamb carcasses. The fat carcasses when analyzed showed about 33 per cent. separable fat, 48 per cent. separable lean, and 19 per cent. bone. The intermediate lamb showed about 22 per cent. fat, 56 per cent. lean, and 22 per cent. bone. The thin, approximately 11 per cent. fat, 58 per cent. lean, and 31 per cent. bone. While thin lambs have a higher percentage of lean, the bone content also is greater and the total edible portion less. Chemical analysis of the edible portions did not show a wide variation in protein content for the three classes. However, the fat lambs contained about 40 per cent. fat and 46 per cent. water, compared with approximately 15 per cent. fat and 66 per cent. water for the thin lambs.

R. H. O.

The Production of Active Carbon from Bituminous Coal.—Active carbons are used today for a variety of industrial purposes such as the removal of colored impurities from liquids, the recovery of solvents in manufacturing processes, the purification of water, the deodorization of liquid or gaseous effluents before disposal, and the filling of respirators for use in atmospheres containing poisonous gases. In Great Britain the War Office approached the Department of Scientific and Industrial Research with a proposal for an investigation to be carried out jointly by the Research organization and the Chemical Defence Research Department, into the possibility of producing from lump coal an active carbon which would be suitable for use in gas respirators. Technical Paper No. 47, by J. G. King, D. Mac Dougall, and H. Gilmour describes the course of the investigation. It shows that at least one type of carbon of the highest quality can be made, and there is sufficient promise in the preparation of other types to justify further research. It is considered that the plant available in the carbonizing industries could be adapted for this purpose. Activated coke is prepared by carbonizing carefully selected coals of the hard durain type which do not intumesce on carbonization at 500° C. The process consists of carbonizing the graded coal below 500° C. and treating the resulting coke with steam or steam and air in a continuous-vertical retort at about 950° C. During this process about 75 per cent. of the coke is gasified, and a 25 per cent. yield of activated coke is obtained, which, by crushing and grading, can be made into graded activated carbon. When graded to the correct size carbon equal to a first grade commercial carbon for gas respirators can be made. About 70 per cent. of this material can be made from activated coke. Further research and treatment of other sizes may be necessary for other uses.

R. H. O.

Synthetic Substances With Rubber-Like Properties.—E. R. BRIDGWATER. (*Mechanical Engineering*, Vol. 60, No. 10.) Today a great profusion of more or less rubber-like synthetic products is available to the engineering profession—a profusion that must be confusing to engineers who have not had opportunity or occasion to make a careful survey of the field. As a result there may be a tendency to draw broad generalizations in terms that are devoid of exact meaning. It is a fact, however, that the products included in the broad terms "synthetic rubbers" and "synthetic rubber-like materials" have little in common except the ability to stretch to several times their initial length before breaking. In fact, there is less similarity between some of these synthetic products and others than there is between some of them and natural rubber. Moreover the properties of some of these synthetic products may be varied over such a wide range by compounding with other ingredients and vulcanizing under varying conditions that it is unsafe to generalize about any of them. The only way to ascertain whether a rubber-like synthetic product will be suitable for a specific use is to analyze the conditions of service, prepare a composition whose properties approach as closely as possible the ideal revealed by that analysis, and test that composition under conditions related as closely as possible to those that may be encountered in service. It will probably never be possible to tabulate the properties of rubber-like synthetics in so comprehensive a manner that the engineer will be able to select the right product for any particular use by consulting a handbook. Today, at least, it is true that any general tables of properties that may be prepared would be so misleading as to do more harm than good. The engineer who would use rubber or rubber-like synthetics wisely must accept these facts and work within the limitations imposed by them.

R. H. O.

Erosion Remedies Must Fit Local Conditions.—Rule-of-thumb solutions do not apply to soil erosion problems. A successful soil and water conservation program for any farming section must always be based on local conditions—on existing soil types and topography, on probable climate, and on economic conditions—says H. H. Bennett, Chief of the Soil Conservation Service. Bennett cites the program developed for the wheatlands of the southern Great Plains. In this region where soil blowing is a serious hazard, many erosion control methods successful in humid areas are impracticable. Because of climatic irregularities, systematic crop rotations are undesirable. Soils and seasonal conditions are unfavorable to the growth of legumes. Low rainfall rules out the type of terrace

system used in the more humid regions, because the primary problem is one of holding water on the land rather than draining it off safely. But Soil Conservation Service technicians have worked out a program that does apply. Water is conserved through contour tillage and terracing to promote vegetative cover. Variable crop rotations are guided by seasonal, climatic, and soil conditions—with wheat the major crop and sorghum feed grains the minor crop. Crop residues such as stalks and stubble prevent wind erosion. Small grains are marketed and the feed grains utilized by permanent or transient livestock—depending on the availability of grazing land in the neighborhood. Feed storage facilities, at least a 2-year feed reserve, are recommended to relieve grazing pressure on stalk fields, permanent pastures, and young crops.

R. H. O.

Fibers Made of Casein Will "Take" Wool Dyes.—Different dyes are required in coloring animal fibers and plant fibers because of different chemical compositions. To the textile trade dyes used in coloring animal fibers are known as "wool" dyes, and those for plant fibers as "cotton" dyes, as they are the most common animal and plant fibers. Blending a plant fiber with wool has been a problem to manufacturers because of the different dyes required. While some rayons—synthetic plant fibers—will take wool dyes, the color is always a different shade. Synthetic wool fiber made from casein, a milk byproduct, under a process recently devised by scientists of the Bureau of Dairy Industry, is of animal origin and therefore takes wool dyes. In fact, the chemical composition of casein fiber and natural wool is almost identical. The synthetic fiber contains somewhat less sulphur which does not affect the wool dyes in any way. The casein fiber also has the characteristic fine kink of natural wool and may be blended with it to make a product that has the resilience of pure wool. Manufacturers have been able to make rayon fibers with this same kinky structure, but because they do not take wool dyes, they are not as desirable for blending with wool as fibers from animal products.

R. H. O.

Research on Watch Technology Sponsored at Mellon Institute by The Elgin National Watch Company.—Dr. E. R. WEIDLEIN, Director of Mellon Institute, Pittsburgh, Pa., has announced the establishment of an Industrial Fellowship by the Elgin National Watch Company, Elgin, Illinois. The research program will cover broadly the chemical aspects of the technical problems in the watch industry. One of the first subjects of investigation will be watch

lubrication. George E. Barker, Ph.D., Massachusetts Institute of Technology, 1934, has been appointed incumbent of the Fellowship. Before joining the Institute's research staff, Dr. Barker spent several years in the synthetic organic chemical industry.

R. H. O.

Nickel Alloys in 1938.—The current year witnessed continued expansion and diversification of the use of alloys containing nickel, an increasingly large number of parts of machinery and equipment of all types now being fabricated from a variety of alloys of which nickel is an influential constituent. Considerable interest has been shown in ferro-nickel alloys, the wide range of properties obtainable by varying the nickel/iron ratio being utilized in a number of interesting applications although the bulk of the ferro-nickel alloys produced are still of the Invar type and are used largely in thermostatic bi-metals. Another special high nickel alloy, a combination of nickel, cobalt, aluminum and iron, has worked out surprisingly well for permanent magnets, developing higher coercive force than other magnetic materials available, and being moderate in cost. Because of their special properties, the use of magnets of this type permits of unusually compact design, and many devices formerly manufactured with wire wound magnets are now being built of permanent magnets of this type. Recent developments in nickel plating include the so-called bright nickel plating process, the introduction of automatic machinery, and the depositing of heavy coatings at high current densities. It is now possible to plate continuously strip steel and fabricate pressed and drawn articles directly from this product. Many articles which would be difficult to buff in the fabricated state can be made from steel strip plated in this manner and, as buffing is the most important cost item in nickel plating, the overall cost of the product can be materially reduced. Among the non-ferrous developments of importance during the past 12 months has been the development of Z nickel, a heat-treatable alloy containing 98 per cent. pure nickel which, in certain forms, has been produced with a tensile strength as high as 250,000 psi and hardness values up to 46 Rockwell C. The alloy retains all the corrosion resistance and other properties of nickel.

R. H. O.